THE HANDBOOK of ELECTRONIC TABLES

THE HANDBOOK of ELECTRONIC TABLES

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To Kenneth, Paul and Jerrold

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Contents

introduction

Problems in electronics can be solved in a number of ways. Possibly the most common method is to use a formula and to plug in or substitute numerical values. This technique calls for some arithmetic dexterity, and, quite often, a good working knowledge of algebraic and trigonometric functions. Aside from the work involved, the use of a formula has the disadvantage in that it supplies a single solution.

This disadvantage is overcome by the use of nomographs. A nomograph not only gives the desired solution to a problem, but also supplies the user with a fairly good number of alternate possibilities. Thus, nomographs are well-suited for the designer who is not only interested in the solution to a problem, but is confronted with the need for specifying practical and easily-obtained components. The ideal solution to a problem is not always the most practical one.

This book represents still another way of solving electronics problems. It consists of electronics data arranged in tabular form. In a few instances some arithmetic may be needed, but for the most part, if the elements of a problem are known, the answer is supplied immediately by a table.

The tables in this book are based on formulas commonly used in electronics. Many of the tables supply answers with a much higher order of accuracy than is generally needed in the solution of problems in electronics. Also, as in the case of nomographs, the tables supply a number of possible solutions, allowing the user a choice of practical component values that may be needed for a circuit.

There is a limit to the number of electronics tables that can be prepared. Tables are easily developed when only two variables are involved. Thus, it is simple enough to set up a table for capacitors in series or for resistance vs conductance. For involved formulas it is better to use the formulas directly, or to use nomographs if these are available.

What is the purpose of having a book of tables? Its only function is to save time and work. Actually, there is no single best method for problem solving. Those who must solve problems in electronics as part of their educational training or work will find it helpful to be able to have a variety of techniques at their command — solving problems by formulas, solving problems by nomographs, and, with the help of this book, solving problems by tables.

I wish to thank the Digital Equipment Corporation, Maynard, Massachusetts for their kind permission to use their Powers of Two Table. My thanks also go to my friend Marcus G. Scroggie and to Iliffe Books Ltd. for granting permission to use the Decibel Table that originally appeared in his Radio Laboratory Handbook, and to Dr. Bernhard Fischer and the Macmillan Company for the use of their Vector Conversion Table.

MARTIN CLIFFORD

Equivalent resistance — resistors in parallel

Whenever two resistors are connected in parallel, the total value of the shunt combination must always be less than that of the value of the smaller unit. From a practical viewpoint, if one of the two parallel resistors has a value that is ten or more times that of the other resistor, the equivalent value can be taken as being approximately equal to that of the smaller resistor. Use Table 1 on pages 7, 8 and 9 to find the equivalent resistance of two resistors in parallel.

The Tables shown on the following pages can also be used to find the equivalent resistance of three or more resistors in parallel if the problem is handled on a step-by-step basis. First, take any two of the resistors, and, using the Tables, find the equivalent resistance. Consider this equivalent resistance just as though it were a physical unit and combine its value with the remaining resistor, again using the Tables.

Sometimes a design problem involving resistors will yield a value that is not practical — not practical in the sense that a resistor having such a value will be unavailable. In this instance the Tables can again be used to advantage. Simply locate the nearest value in the Tables and then move left to get the value of R2 and upward to get the value of R1. R1 and R2 will be standard, available resistors, which can be connected in parallel to supply the resistance called for by your design.

Examples:

What is the equivalent resistance of two resistors in parallel, one having a value of 5.6 and the other a value of 9.1 ohms?

Locate 5.6 at the left, in the column marked *R2*. Move across until you locate the column headed by 9.1. The equivalent resistance is shown to be 3.46 ohms.

What two resistors in parallel will give an equivalent value of 3 ohms?

The Table shows possible combinations. You could use 3.3 and 33 ohms, or 3.6 and 18 ohms, or 3.9 and 13 ohms.

What is the equivalent shunt resistance of a 68-ohm resistor and a 27-ohm resistor in parallel?

Locate 6.8 ohms in the *R1* column. Move the decimal point one place to the right so that 6.8 becomes 68. Locate 2.7 ohms in the *R2* column and consider it now as 27 ohms. These two values meet at 1.93 in the Table. However, this is now 19.3 ohms, since you must move the decimal point one place to the right.

Table 1 — Equivalent Resistance of Two Resistors in Parallel

	R1							
R2	*2.7*	*3.0*	*3.3*	*3.6*	*3.9*	*4.3*	*4.7*	*5.1*
2.7	1.35	1.42	1.48	1.54	1.59	1.66	1.71	1.76
3.0	1.42	1.50	1.57	1.64	1.69	1.76	1.83	1.88
3.3	1.48	1.57	1.65	1.72	1.78	1.86	1.94	2.00
3.6	1.54	1.64	1.72	1.80	1.87	1.96	2.04	2.11
3.9	1.59	1.69	1.78	1.87	1.95	2.04	2.13	2.21
4.3	1.66	1.76	1.86	1.96	2.04	2.15	2.24	2.33
4.7	1.71	1.83	1.94	2.04	2.13	2.24	2.35	2.44
5.1	1.76	1.88	2.00	2.11	2.21	2.33	2.44	2.55
5.6	1.82	1.95	2.07	2.19	2.29	2.43	2.55	2.67
6.2	1.88	2.02	2.15	2.27	2.39	2.54	2.67	2.79
6.8	1.93	2.08	2.22	2.35	2.48	2.63	2.78	2.91
7.5	1.98	2.14	2.29	2.43	2.57	2.73	2.88	3.03
8.2	2.03	2.19	2.35	2.50	2.64	2.82	2.99	3.14
9.1	2.08	2.25	2.42	2.58	2.73	2.92	3.09	3.26
10	2.12	2.31	2.48	2.65	2.81	3.01	3.19	3.37
11	2.16	2.35	2.53	2.71	2.87	3.09	3.29	3.48
12	2.20	2.40	2.59	2.77	2.94	3.16	3.37	3.59
13	2.23	2.43	2.63	2.82	3.00	3.23	3.44	3.66
15	2.29	2.50	2.72	2.90	3.09	3.34	3.57	3.80
16	2.31	2.52	2.73	2.94	3.13	3.39	3.63	3.87
18	2.34	2.57	2.79	3.00	3.20	3.47	3.73	3.97
20	2.37	2.65	2.83	3.05	3.26	3.54	3.80	4.06
22	2.40	2.64	2.87	3.09	3.31	3.59	3.87	4.14
24	2.43	2.66	2.90	3.13	3.35	3.64	3.92	4.20
27	2.45	2.70	2.94	3.17	3.40	3.70	4.00	4.29
30	2.48	2.73	2.97	3.21	3.45	3.76	4.06	4.36
33	2.49	2.75	3.00	3.24	3.49	3.80	4.11	4.41
36	2.51	2.77	3.02	3.27	3.51	3.84	4.15	4.46
39	2.52	2.78	3.04	3.29	3.54	3.87	4.19	4.51
43	2.54	2.80	3.07	3.32	3.57	3.91	4.23	4.56
47	2.55	2.82	3.08	3.34	3.60	3.94	4.27	4.60
51	2.56	2.83	3.09	3.36	3.62	3.96	4.30	4.63
56	2.57	2.84	3.11	3.38	3.64	3.99	4.33	4.67
62	2.58	2.86	3.13	3.40	3.66	4.01	4.36	4.71
68	2.59	2.88	3.14	3.42	3.68	4.04	4.39	4.74

Table 1 — Equivalent Resistance of Two Resistors in Parallel

				R1			
R2	5.6	6.2	6.8	7.5	8.2	9.1	10.
2.7	1.82	1.88	1.93	1.98	2.03	2.08	2.12
3.0	1.95	2.02	2.08	2.14	2.19	2.25	2.31
3.3	2.07	2.15	2.22	2.29	2.35	2.42	2.48
3.6	2.19	2.27	2.35	2.43	2.50	2.58	2.65
3.9	2.29	2.39	2.48	2.57	2.64	2.73	2.81
4.3	2.43	2.54	2.63	2.73	2.82	2.92	3.01
4.7	2.55	2.67	2.78	2.88	2.99	3.09	3.19
5.1	2.67	2.79	2.91	3.03	3.14	3.26	3.37
5.6	2.80	2.94	3.07	3.21	3.32	3.46	3.59
6.2	2.94	3.10	3.24	3.39	3.53	3.68	3.83
6.8	3.07	3.24	3.40	3.56	3.66	3.89	4.05
7.5	3.21	3.39	3.56	3.75	3.92	4.11	4.29
8.2	3.32	3.53	3.66	3.92	4.10	4.31	4.51
9.1	3.46	3.68	3.89	4.11	4.31	4.55	4.76
10	3.59	3.83	4.05	4.29	4.51	4.76	5.00
11	3.71	3.96	4.20	4.46	4.69	4.98	5.24
12	3.82	4.09	4.34	4.61	4.87	5.17	5.45
13	3.91	4.19	4.46	4.75	5.03	5.35	5.65
15	4.08	4.39	4.68	5.00	5.30	5.65	6.00
16	4.15	4.47	4.77	5.10	5.42	5.80	6.15
18	4.27	4.61	4.93	5.29	5.63	6.04	6.43
20	4.37	4.73	5.07	5.45	5.81	6.25	6.66
22	4.46	4.83	5.19	5.59	5.97	6.43	6.87
24	4.54	4.92	5.29	5.71	6.11	6.59	7.06
27	4.63	5.04	5.43	5.87	6.29	6.80	7.29
30	4.71	5.13	5.54	6.00	6.44	6.98	7.50
33	4.78	5.22	5.64	6.11	6.57	7.13	7.67
36	4.84	5.29	5.72	6.20	6.67	7.26	7.82
39	4.89	5.35	5.79	6.29	6.77	7.37	7.95
43	4.95	5.42	5.87	6.38	6.88	7.51	8.11
47	5.00	5.47	5.94	6.47	6.98	7.62	8.24
51	5.04	5.52	6.00	6.53	7.06	7.72	8.36
56	5.09	5.58	6.06	6.61	7.15	7.82	8.48
62	5.13	5.63	6.14	6.69	7.24	7.93	8.61
68	5.17	5.68	6.18	6.75	7.32	8.02	8.72

Table 1 — Equivalent Resistance of Two Resistors in Parallel

				R1			
R2	39	47	56	68	82	91	100
39	19.5	21.3	22.9	24.8	26.4	27.3	28.1
43	20.4	22.4	24.3	26.3	28.2	29.2	30.1
47	21.3	23.5	25.5	27.8	29.9	30.9	31.9
51	22.1	24.4	26.7	29.1	31.4	32.6	33.7
56	22.9	25.5	28.0	30.7	33.2	34.6	35.9
62	23.9	26.7	29.4	32.4	35.3	36.8	38.3
68	24.8	27.8	30.7	34.0	36.6	38.9	40.5
75	25.7	28.8	32.1	35.6	39.2	41.1	42.9
82	26.4	29.9	33.2	36.6	41.0	43.1	45.1
91	27.3	30.9	34.6	38.9	43.1	45.5	47.6
100	28.1	31.9	35.9	40.5	45.1	47.6	50.0
110	28.7	32.9	37.1	42.0	46.9	49.8	52.4
120	29.4	33.7	38.2	43.4	48.7	51.7	54.5
130	30.0	34.4	39.1	44.6	50.3	53.5	56.5
150	30.9	35.7	40.8	46.8	53.0	56.5	60.0
160	31.3	36.3	41.5	47.7	54.2	58.0	61.5
180	32.0	37.3	42.7	49.3	56.3	60.4	64.3
200	32.6	38.0	43.7	50.7	58.1	62.5	66.6
220	33.1	38.7	44.6	51.9	59.7	64.3	68.7
240	33.5	39.2	45.4	52.9	61.1	65.9	70.6
270	34.0	40.0	46.3	54.3	62.9	68.0	72.9
300	34.5	40.6	47.1	55.4	64.4	69.8	75.0
330	34.9	41.1	47.8	56.4	65.7	71.3	76.7
360	35.1	41.5	48.4	57.2	66.7	72.6	78.2
390	35.4	41.9	48.9	57.9	67.7	73.7	79.5
430	35.7	42.3	49.5	58.7	68.8	75.1	81.1
470	36.0	42.7	50.0	59.4	69.8	76.2	82.4
510	36.2	43.0	50.4	60.0	70.6	77.2	83.6
560	36.4	43.3	50.9	60.6	71.5	78.2	84.8
620	36.6	43.6	51.3	61.4	72.4	79.3	86.1
680	36.8	43.9	51.7	61.8	73.2	80.2	87.2
750	37.1	44.2	52.1	62.3	73.9	81.1	88.2
820	37.2	44.5	52.4	62.8	74.5	81.9	89.1
910	37.4	44.7	52.7	63.2	75.2	82.7	90.1
1000	37.5	44.9	53.0	63.7	75.8	83.4	90.9

Resistance vs conductance

The opposition to the movement of an electrical current can be expressed in terms of resistance (measured in ohms) or in terms of conductance (expressed in mhos). It is often very convenient to be able to move back and forth quickly and easily between resistance and conductance in the solution of electronics problems. This is easily done since resistance and conductance are reciprocals.

Sometimes, in working with resistances you will find that the values are such that they are not covered by the Tables and that using a formula to solve the problem will involve some laborious arithmetic. In that case it may be easier and quicker to work with conductances. To find the total conductance of resistors in parallel simply consider them as conductors and add the values of the individual units. Thus, if you have a number of resistors in parallel, use Table 2 to find the equivalent conductance of each resistor. Add the conductances and then use the Table once again to find the equivalent resistance.

The symbol for resistance is R; that used for conductance is G. The relationship between the two is simply expressed as $R = 1/G$ or $G = 1/R$. If you are considering a complete circuit, that is a circuit consisting of a number of resistors in parallel, then the total resistance of the circuit is the reciprocal of the total conductance.

Conductance can be substituted into the different forms of Ohm's law. Thus, for resistance, we would have $R = E/I$. For conductance we would have $G = I/E$.

Examples:

What is the conductance of a resistor whose value, as measured, is 64 ohms?

Locate 64 in the column marked *ohms*. The value of conductance, as shown in the column *(mhos)* to the right, is 0.0156 mhos.

What is the resistance of a component whose conductance is 0.0556 mho?

The value of 0.0556, in the *mhos* column, corresponds to 18 ohms, as indicated in the *ohms* column.

The values of four resistors, measured on a bridge, are 90 ohms, 83, 79 and 71 ohms respectively. What is the equivalent resistance when these units are connected in parallel?

Using Table 2 you will find that the corresponding conductance values are .0111, .0120, .0127 and .0141 mhos, respectively. Adding these results in a total conductance of .0499 mhos. Using Table 2 once again, the closest conductance value is 0.0500 mho, and, as shown by the Table, corresponds to 20 ohms.

Table 2 — Resistance (Ohms) vs Conductance (Mhos)

Ohms	Mhos	Ohms	Mhos	Ohms	Mhos
0.1	10.0000	28	0.0357	64	0.0156
0.2	5.0000	29	0.0345	65	0.0154
0.3	3.3333	30	0.0333	66	0.0152
0.4	2.5000	31	0.0323	67	0.0149
0.5	2.0000	32	0.0312	68	0.0147
0.6	1.6666	33	0.0303	69	0.0145
0.7	1.4286	34	0.0294	70	0.0143
0.8	1.2500	35	0.0286	71	0.0141
0.9	1.1111	36	0.0278	72	0.0139
1.0	1.0000	37	0.0270	73	0.0137
2	0.5000	38	0.0263	74	0.0135
3	0.3333	39	0.0256	75	0.0133
4	0.2500	40	0.0250	76	0.0132
5	0.2000	41	0.0244	77	0.0130
6	0.1666	42	0.0238	78	0.0128
7	0.1428	43	0.0233	79	0.0127
8	0.1250	44	0.0227	80	0.0125
9	0.1111	45	0.0222	81	0.0123
10	0.1000	46	0.0217	82	0.0122
11	0.0909	47	0.0213	83	0.0120
12	0.0833	48	0.0208	84	0.0119
13	0.0769	49	0.0204	85	0.0118
14	0.0714	50	0.0200	86	0.0116
15	0.0667	51	0.0196	87	0.0115
16	0.0625	52	0.0192	88	0.0114
17	0.0588	53	0.0189	89	0.0112
18	0.0556	54	0.0185	90	0.0111
19	0.0526	55	0.0182	91	0.0110
20	0.0500	56	0.0179	92	0.0109
21	0.0476	57	0.0175	93	0.0108
22	0.0455	58	0.0172	94	0.0106
23	0.0435	59	0.0169	95	0.0105
24	0.0417	60	0.0167	96	0.0104
25	0.0400	61	0.0164	97	0.0103
26	0.0385	62	0.0161	98	0.0102
27	0.0370	63	0.0159	99	0.0101
				100	0.0100

Standard values for composition resistors

Composition resistors are available in values based on the recommendations of the Electronics Industries Association (EIA). These values are shown below in Table 3.

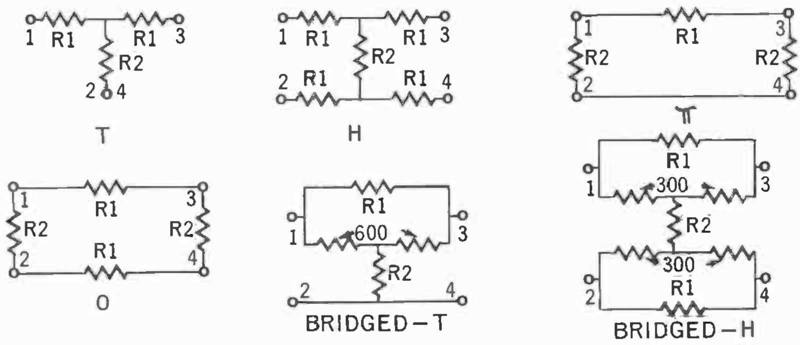
Table 3 — Standard EIA Values for Composition Resistors

Ohms	Ohms	Ohms	Ohms	Ohms	Ohms
2.7*	39*	560*	8.2K*	120K*	1.8 Meg*
3.0	43	620	9.1K	130K	2.0 Meg
3.3*	47*	680*	10K*	150K*	2.2 Meg*
3.6	51	750	11K	160K	2.4 Meg
3.9*	56*	820*	12K*	180K*	2.7 Meg*
4.3	62	910	13K	200K	3.0 Meg
4.7*	68*	1K*	15K*	220K*	3.3 Meg*
5.1	75	1.1K	16K	240K	3.6 Meg
5.6*	82*	1.2K*	18K*	270K*	3.9 Meg*
6.2	91	1.3K	20K	300K	4.3 Meg
6.8*	100*	1.5K*	22K*	330K*	4.7 Meg*
7.5	110	1.6K	24K	360K	5.1 Meg
8.2*	120*	1.8K*	27K*	390K*	5.6 Meg*
9.1	130	2K	30K	430K	6.2 Meg
10*	150*	2.2K*	33K*	470K*	6.8 Meg*
11	160	2.4K	36K	510K	7.5 Meg
12*	180*	2.7K*	39K*	560K*	8.2 Meg*
13	200	3K	43K	620K	9.1 Meg
15*	220*	3.3K*	47K*	680K*	10 Meg*
16	240	3.6K	51K	750K	11 Meg
18*	270*	3.9K*	56K*	820K*	12 Meg*
20	300	4.3K	62K	910K	13 Meg
22*	330*	4.7K*	68K*	1 Meg*	15 Meg*
24	360	5.1K	75K	1.1 Meg	16 Meg
27*	390*	5.6K*	82K*	1.2 Meg*	18 Meg*
30	430	6.2K	91K	1.3 Meg	20 Meg
33*	470*	6.8K*	100K*	1.5 Meg*	22 Meg*
36	510	7.5K	110K	1.6 Meg	......

Resistances shown with asterisk (*) available only in 10% tolerance.
All resistance values shown are available in 5% tolerance.

Fixed attenuators

The insertion loss of a fixed attenuator network, or pad, is the ratio of the power input to power output, given in db, and assuming equal impedances for the source and the load. Table 4 is for use where these impedances are the same. The values in the Table are based on input and output impedances of 600 ohms. The illustrations below show the types of pads for which Table 4 may be used.



Attenuator pads. Design values for these networks are given in Table 4 on pages 14, 15 and 16.

Examples:

A simple pad is required to supply an insertion loss of 40 db. How many resistors are needed and what is their value?

A T-pad can be used to solve this problem. The circuit is a 4-terminal network as shown in the corresponding circuit diagram. Locate 40 db in the left-hand column. To the right of this is given the values for R1 and R2. R1 represents two resistors, each having a value of 588.1 ohms. R2 is shown as 12 ohms. Note that a π pad could also be used to supply the same insertion loss, except that 30,000 ohms is needed for R1 while R2 consists of two resistors each of which is 612.1 ohms. The nearest equivalent values can be selected from Table 3 on page 12, or series and parallel combinations can be used to obtain the required resistance.

It is necessary to drop the output voltage of a 600-ohm source by 3 db. What type of pad can do this, and what are the values of the resistors in the attenuator?

Find the number 3 in the column headed *Loss, db*. As shown in the Table, a number of different pads can be used to get the same result. For an H-pad, four resistors (R1) will be needed, each having a value of 51.3 ohms. A single resistor (R2) of 1703 ohms will complete the network.

Table 4 — Design Values for Attenuator Networks

Loss, db	*R1*	*R2*	*R1*	*R2*	*R1*	*R2*
0.1	3.58	50204	1.79	50204	7.20	100500
0.2	6.82	26280	3.41	26280	13.70	57380
0.3	10.32	17460	5.16	17460	20.55	34900
0.4	13.79	13068	6.90	13068	27.50	26100
0.5	17.20	10464	8.60	10464	34.40	20920
0.6	20.9	8640	10.45	8640	41.7	17230
0.7	24.2	7428	12.1	7428	48.5	14880
0.8	27.5	6540	13.75	6540	55.05	13100
0.9	31.02	5787	15.51	5787	62.3	11600
1.0	34.5	5208	17.25	5208	68.6	10440
2.0	68.8	2582	34.4	2582	139.4	5232
3.0	102.7	1703	51.3	1703	212.5	3505
4.0	135.8	1249	67.9	1249	287.5	2651
5.0	168.1	987.6	84.1	987.6	364.5	2141
6.0	199.3	803.4	99.7	803.4	447.5	1807
7.0	229.7	685.2	114.8	685.2	537.0	1569
8.0	258.4	567.6	129.2	567.6	634.2	1393
9.0	285.8	487.2	142.9	487.2	738.9	1260
10.0	312.0	421.6	156.0	421.6	854.1	1154
11.0	336.1	367.4	168.1	367.4	979.8	1071
12.0	359.1	321.7	179.5	321.7	1119	1002
13.0	380.5	282.8	190.3	282.8	1273	946.1
14.0	400.4	249.4	200.2	249.4	1443	899.1
15.0	418.8	220.4	209.4	220.4	1632	859.6
16.0	435.8	195.1	217.9	195.1	1847	826.0
17.0	451.5	172.9	225.7	172.9	2083	797.3
18.0	465.8	152.5	232.9	152.5	2344	772.8
19.0	479.0	136.4	239.5	136.4	2670	751.7
20.0	490.4	121.2	245.2	121.2	2970	733.3
22.0	511.7	95.9	255.9	95.9	3753	703.6
24.0	528.8	76.0	264.4	76.0	4737	680.8
26.0	542.7	60.3	271.4	60.3	5985	663.4
28.0	554.1	47.8	277.0	47.8	7550	649.7
30.0	563.0	37.99	281.6	37.99	9500	639.2
32.0	570.6	30.16	285.3	30.16	11930	630.9
34.0	576.5	23.95	288.3	23.95	15000	624.4
36.0	581.1	18.98	290.6	18.98	18960	619.3
38.0	585.1	15.11	292.5	15.11	23820	615.3
40.0	588.1	12.00	294.1	12.00	30000	612.1

Table 4 — Design Values for Attenuator Networks

Loss, db	*R1*	*R2*	*R1*	*R2*
0.1	3.60	100500	3.58	100500
0.2	6.85	57380	6.82	57380
0.3	10.28	34900	10.32	34900
0.4	13.80	26100	13.79	26100
0.5	17.20	20920	17.20	20920
0.6	20.85	17230	20.9	17230
0.7	24.25	14880	24.2	14880
0.8	27.53	13100	27.5	13100
0.9	31.2	11600	31.02	11600
1.0	34.3	10440	34.5	10440
2.0	69.7	5232	68.8	5232
3.0	106.2	3505	102.7	3505
4.0	143.8	2651	135.8	2651
5.0	182.3	2141	168.1	2141
6.0	223.8	1807	199.3	1807
7.0	268.5	1569	229.7	1569
8.0	317.1	1393	258.4	1393
9.0	369.4	1260	285.8	1260
10.0	427.0	1154	312.0	1154
11.0	489.9	1071	336.1	1071
12.0	559.5	1002	359.1	1002
13.0	636.3	946.1	380.5	946.1
14.0	721.5	899.1	400.4	899.1
15.0	816.0	859.6	418.8	859.6
16.0	923.2	826.0	435.8	826.0
17.0	1042	797.3	451.5	797.3
18.0	1172	772.8	465.8	772.8
19.0	1335	751.7	479.0	751.7
20.0	1485	733.3	490.4	733.3
22.0	1877	703.6	511.7	703.6
24.0	2369	680.8	528.8	680.8
26.0	2992	663.4	542.7	663.4
28.0	3775	649.7	554.1	649.7
30.0	4750	639.2	563.2	639.2
32.0	5967	630.9	570.6	630.9
34.0	7500	624.4	576.5	624.4
36.0	9480	619.3	581.1	619.3
38.0	11910	615.3	585.1	615.3
40.0	15000	612.1	588.1	612.1

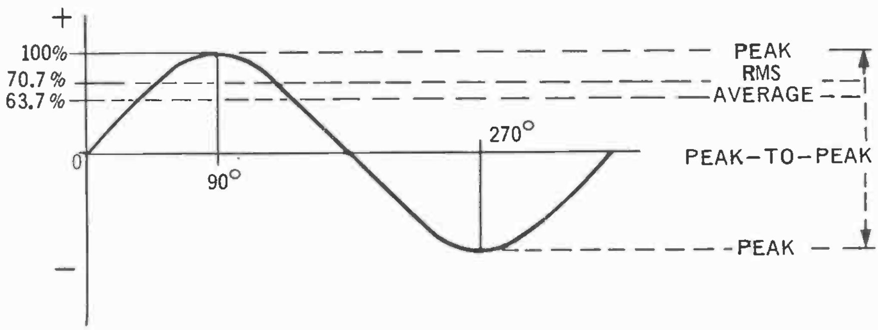
Table 4 — Design Values for Attenuator Networks

Loss, db	*R1*	*R2*	*R1*	*R2*
0.1	7.2	50000	3.6	50000
0.2	13.8	26086	6.9	26086
0.3	21.0	17143	10.5	17143
0.4	28.2	12766	14.1	12766
0.5	35.4	10169	17.7	10169
0.6	43.2	8333	21.6	8333
0.7	50.4	7143	25.2	7143
0.8	57.6	6250	28.8	6250
0.9	65.4	5504	32.7	5504
1.0	73.2	4918	36.6	4918
2.0	155.4	2316	77.7	2316
3.0	247.8	1452	123.9	1452
4.0	351.0	1025	175.5	1025
5.0	466.8	771.2	233.4	771.2
6.0	597.0	603.0	298.5	603.0
7.0	743.4	484.3	371.7	484.3
8.0	907.2	396.8	453.6	396.8
9.0	1091	329.9	545.5	329.9
10.0	1297	277.5	648.5	277.5
11.0	1529	235.5	764.5	235.5
12.0	1788	201.3	894	201.3
13.0	2080	173.1	1040	173.1
14.0	2407	149.6	1204	149.6
15.0	2773	129.8	1387	129.8
16.0	3186	113.0	1598	113.0
17.0	3648	98.68	1824	98.68
18.0	4166	86.4	2083	86.4
19.0	4748	75.8	2374	75.8
20.0	5400	66.66	2700	66.66
22.0	6954	51.72	3477	51.72
24.0	8910	40.4	4455	40.4
26.0	11370	31.66	5685	31.66
28.0	14472	24.87	7236	24.87
30.0	18372	19.58	9186	19.58
32.0	23286	15.46	11643	15.46
34.0	29472	12.21	14736	12.21
36.0	37260	9.66	18630	9.66
38.0	47058	7.65	23529	7.65
40.0	59400	6.06	29700	6.06

Peak, peak-to-peak, average and rms (effective) values of currents or voltages of sine waves

The peak value of a sine wave of voltage or current is measured at either 90° or 270°. For this reason the peak (or peak-to-peak) values may be considered as instantaneous values. The average of all the instantaneous values over a complete cycle is zero; hence average is generally understood to be the average of the instantaneous values over a half cycle. The effective or root-mean-square (rms) value is also a form of instantaneous value averaging.

The data in Table 5 allows rapid movement among peak, peak-to-peak, average and rms values of currents or voltages of sine waves.



Relationships between peak, peak-to-peak, average and rms values of sine waves of voltage or current.

Examples:

What is the peak value of a sine wave current whose effective value is measured as 17½ volts?

Locate the nearest value in the *rms* (effective) column. This is 17.675. Move to the left along the same line and locate 25 as your answer in the column marked *peak*.

What is the average value of a voltage sine wave whose peak value is 160 volts?

The maximum peak value shown in Table 5 is 100. You can extend the Table, however, by multiplying each value by 10. Do this by adding a zero to the right of each whole number. Thus, in the *peak* column, 16 becomes 160. Move to the right and locate 10.191 in the *average* column. You can multiply this value by 10 by moving the decimal point one place to the right. The average value is 101.91 volts.

Table 5 — Peak, Peak-to-Peak, Average and RMS (Effective) Values of Currents or Voltages of Pure, Symmetric Sinusoids

Peak	*Peak-to-Peak*	*Average*	*RMS*
1	2	0.637	0.707
2	4	1.274	1.414
3	6	1.911	2.121
4	8	2.548	2.828
5	10	3.185	3.535
6	12	3.822	4.242
7	14	4.459	4.949
8	16	5.096	5.656
9	18	5.733	6.363
10	20	6.369	7.070
11	22	7.006	7.777
12	24	7.643	8.484
13	26	8.280	9.191
14	28	8.917	9.898
15	30	9.554	10.605
16	32	10.191	11.312
17	34	10.828	12.019
18	36	11.465	12.726
19	38	12.102	13.433
20	40	12.738	14.140
21	42	13.375	14.847
22	44	14.012	15.554
23	46	14.649	16.261
24	48	15.286	16.968
25	50	15.923	17.675
26	52	16.560	18.382
27	54	17.197	19.089
28	56	17.834	19.796
29	58	18.471	20.503
30	60	19.107	21.210
31	62	19.744	21.917
32	64	20.381	22.625
33	66	21.018	23.332

Table 5 — Peak, Peak-to-Peak, Average and RMS (Effective) Values of Currents or Voltages of Pure, Symmetric Sinusoids

Peak	*Peak-to-Peak*	*Average*	*RMS*
34	68	21.655	24.039
35	70	22.292	24.746
36	72	22.929	25.453
37	74	23.566	26.160
38	76	24.203	26.867
39	78	24.840	27.574
40	80	25.476	28.281
41	82	26.113	28.988
42	84	26.750	29.695
43	86	27.387	30.402
44	88	28.024	31.109
45	90	28.661	31.816
46	92	29.298	32.523
47	94	29.935	33.230
48	96	30.572	33.937
49	98	31.209	34.644
50	100	31.845	35.351
51	102	32.482	36.058
52	104	33.119	36.765
53	106	33.756	37.472
54	108	34.393	38.179
55	110	35.030	38.886
56	112	35.667	39.593
57	114	36.304	40.300
58	116	36.941	41.007
59	118	37.578	41.714
60	120	38.214	42.421
61	122	38.851	43.128
62	124	39.488	43.835
63	126	40.125	44.542
64	128	40.762	45.249
65	130	41.399	45.956
66	132	42.036	46.663

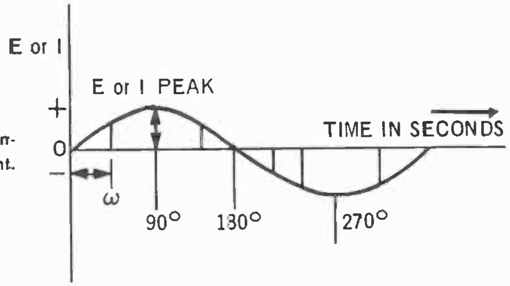
Table 5 — Peak, Peak-to-Peak, Average and RMS (Effective) Values of Currents or Voltages of Pure, Symmetric Sinusoids

Peak	*Peak-to-Peak*	*Average*	*RMS*
67	134	42.673	47.370
68	136	43.310	48.077
69	138	43.947	48.784
70	140	44.583	49.491
71	142	45.220	50.198
72	144	45.857	50.905
73	146	46.494	51.612
74	148	47.131	52.319
75	150	47.768	53.026
76	152	48.405	53.733
77	154	49.042	54.440
78	156	49.679	55.147
79	158	50.316	55.854
80	160	50.952	56.561
81	162	51.589	57.268
82	164	52.226	57.975
83	166	52.863	58.682
84	168	53.500	59.389
85	170	54.137	60.096
86	172	54.774	60.803
87	174	55.411	61.510
88	176	56.048	62.217
89	178	56.685	62.924
90	180	57.321	63.631
91	182	57.958	64.338
92	184	58.595	65.045
93	186	59.232	65.752
94	188	59.869	66.459
95	190	60.506	67.166
96	192	61.143	67.873
97	194	61.780	68.580
98	196	62.417	69.287
99	198	63.054	69.994
100	200	63.693	70.701

Instantaneous values of voltage or current of a sine wave

The instantaneous value of a wave is a function of the phase angle. At 0°, 180° and 360° the instantaneous value is zero. It is a peak at 90° and 270°. These are the only values which may be known without the use of a table or formula. The instantaneous value of a sine voltage *is* $E = E_{max} \sin \omega t$ ($\omega = 2\pi f$) and for a sine current is $I = I_{max} \sin \omega t$. Table 6 gives the instantaneous values of either voltage or current through a complete sine wave cycle of 360° for values of voltage ranging from 1 to 10. Other ranges may be obtained by moving the decimal point.

Sine wave showing various instantaneous values of voltage or current.



Examples:

What is the instantaneous value of current at a phase angle of 37° when the peak value is 3 volts?

Locate 37° in the left-hand column of the Table. Move horizontally until the 3-volt column is reached. The required voltage is 1.8054 volts.

At what phase angle will the instantaneous voltage of a sine wave be 68% of its peak value?

Consider peak as 1 or 100%. Locate the nearest value to 68 in the column headed by the number 1. This value is .6820. If you will move to the left of this number you will see that the phase angle is 43°. Multiples of this value are also given. We have 137° (180° — 43°); 223° (43° + 180°) and 317° (43° + 270°).

What is the instantaneous value of a sine wave of current at a phase angle of 77° when its peak value is 30 ma?

Locate 77° in the left-hand column of the table and move horizontally to the right until you intercept 2.9232 in the column headed by the number 3. However, since we have changed 3 to 30 by multiplying it by 10 (or by moving the decimal point one place to the right) our answer must be similarly treated. The value is 29.232 ma.

Table 6 — Instantaneous Values of Voltage or Current of Sinusoids

Phase Angle (degrees)				Peak Voltage or Current				
				1	2	3	4	5
0	180	180	360	.0000	.0000	.0000	.0000	.0000
1	179	181	359	.0175	.0350	.0525	.0700	.0875
2	178	182	358	.0349	.0698	.1047	.1396	.1745
3	177	183	357	.0523	.1046	.1569	.2092	.2615
4	176	184	356	.0698	.1396	.2094	.2792	.3490
5	175	185	355	.0872	.1744	.2616	.3488	.4360
6	174	186	354	.1045	.2090	.3135	.4180	.5225
7	173	187	353	.1219	.2438	.3657	.4876	.6095
8	172	188	352	.1392	.2784	.4176	.5568	.6960
9	171	189	351	.1564	.3128	.4692	.6256	.7820
10	170	190	350	.1736	.3472	.5208	.6944	.8680
11	169	191	349	.1908	.3816	.5724	.7632	.9540
12	168	192	348	.2079	.4158	.6237	.8316	1.0395
13	167	193	347	.2250	.4500	.6750	.9000	1.1250
14	166	194	346	.2419	.4838	.7257	.9676	1.0095
15	165	195	345	.2588	.5176	.7764	1.0352	1.2940
16	164	196	344	.2756	.5512	.8268	1.1024	1.3780
17	163	197	343	.2924	.5848	.8772	1.1696	1.4620
18	162	198	342	.3090	.6180	.9270	1.2360	1.5450
19	161	199	341	.3256	.6512	.9768	1.3024	1.6280
20	160	200	340	.3420	.6840	1.0260	1.3680	1.7100
21	159	201	339	.3584	.7168	1.0752	1.4336	1.7920
22	158	202	338	.3746	.7492	1.1238	1.4984	1.8730
23	157	203	337	.3907	.7814	1.1721	1.5628	1.9535
24	156	204	336	.4067	.8134	1.2201	1.6268	2.0335
25	155	205	335	.4226	.8452	1.2678	1.6904	2.1130
26	154	206	334	.4384	.8768	1.3152	1.7536	2.1920
27	153	207	333	.4540	.9080	1.3620	1.8160	2.2700
28	152	208	332	.4695	.9390	1.4085	1.8780	2.3475
29	151	209	331	.4848	.9696	1.4544	1.9392	2.4240
30	150	210	330	.5000	1.0000	1.5000	2.0000	2.5000

Table 6 — Instantaneous Values of Voltage or Current of Sinusoids

Phase Angle (degrees)				Peak Voltage or Current				
				1	2	3	4	5
31	149	211	329	.5150	1.0300	1.5450	2.0600	2.5750
32	148	212	328	.5299	1.0598	1.5897	2.1196	2.6495
33	147	213	327	.5446	1.0892	1.6338	2.1784	2.7320
34	146	214	326	.5592	1.1184	1.6776	2.2368	2.7960
35	145	215	325	.5736	1.1472	1.7208	2.2944	2.8680
36	144	216	324	.5878	1.1756	1.7634	2.3512	2.9390
37	143	217	323	.6018	1.2036	1.8054	2.4072	3.0090
38	142	218	322	.6157	1.2314	1.8471	2.4628	3.0785
39	141	219	321	.6293	1.2586	1.8879	2.5172	3.1465
40	140	220	320	.6428	1.2856	1.9284	2.5712	3.2140
41	139	221	319	.6561	1.3122	1.9683	2.6244	3.2805
42	138	222	318	.6691	1.3382	2.0073	2.6764	3.3455
43	137	223	317	.6820	1.3640	2.0460	2.7280	3.4100
44	136	224	316	.6947	1.3894	2.0841	2.7788	3.4735
45	135	225	315	.7071	1.4142	2.1213	2.8284	3.5355
46	134	226	314	.7193	1.4386	2.1579	2.8772	3.5965
47	133	227	313	.7314	1.4628	2.1942	2.9256	3.6570
48	132	228	312	.7431	1.4862	2.2293	2.9724	3.7155
49	131	229	311	.7547	1.5094	2.2641	3.0188	3.7735
50	130	230	310	.7660	1.5320	2.2980	3.0640	3.8300
51	129	231	309	.7771	1.5542	2.3313	3.1084	3.8855
52	128	232	308	.7880	1.5760	2.3640	3.1520	3.9400
53	127	233	307	.7986	1.5972	2.3958	3.1954	3.9930
54	126	234	306	.8090	1.6180	2.4270	3.2360	4.0450
55	125	235	305	.8192	1.6384	2.4576	3.2768	4.0960
56	124	236	304	.8290	1.6580	2.4870	3.3160	4.1450
57	123	237	303	.8387	1.6774	2.5161	3.3548	4.1935
58	122	238	302	.8480	1.6960	2.5440	3.3920	4.2400
59	121	239	301	.8572	1.7144	2.5716	3.4288	4.2860
60	120	240	300	.8660	1.7320	2.5980	3.4640	4.3300

Table 6 — Instantaneous Values of Voltage or Current of Sinusoids

Phase Angle (degrees)				Peak Voltage or Current 1	2	3	4	5
61	119	241	299	.8746	1.7492	2.6238	3.4984	4.3730
62	118	242	298	.8829	1.7658	2.6487	3.5316	4.4145
63	117	243	297	.8910	1.7820	2.6730	3.5640	4.4550
64	116	244	296	.8988	1.7976	2.6964	3.5952	4.4940
65	115	245	295	.9063	1.8126	2.7189	3.6252	4.5315
66	114	246	294	.9135	1.8270	2.7405	3.6540	4.5675
67	113	247	293	.9205	1.8410	2.7615	3.6820	4.6025
68	112	248	292	.9272	1.8544	2.7816	3.7088	4.6360
69	111	249	291	.9336	1.8672	2.8008	3.7344	4.6680
70	110	250	290	.9397	1.8794	2.8191	3.7588	4.6985
71	109	251	289	.9455	1.8910	2.8365	3.7820	4.7275
72	108	252	288	.9511	1.9022	2.8533	3.8044	4.7555
73	107	253	287	.9563	1.9126	2.8689	3.8252	4.7815
74	106	254	286	.9613	1.9226	2.8839	3.8452	4.8065
75	105	255	285	.9659	1.9318	2.8977	3.8636	4.8295
76	104	256	284	.9703	1.9406	2.9109	3.8812	4.8515
77	103	257	283	.9744	1.9488	2.9232	3.8976	4.8720
78	102	258	282	.9781	1.9562	2.9343	3.9124	4.8905
79	101	259	281	.9816	1.9632	2.9448	3.9264	4.9080
80	100	260	280	.9848	1.9696	2.9544	3.9392	4.9240
81	99	261	279	.9877	1.9754	2.9631	3.9508	4.9385
82	98	262	278	.9903	1.9806	2.9709	3.9612	4.9515
83	97	263	277	.9925	1.9850	2.9775	3.9700	4.9625
84	96	264	276	.9945	1.9890	2.9835	3.9780	4.9725
85	95	265	275	.9962	1.9924	2.9886	3.9848	4.9810
86	94	266	274	.9976	1.9952	2.9928	3.9904	4.9880
87	93	267	273	.9986	1.9972	2.9958	3.9944	4.9930
88	92	268	272	.9994	1.9988	2.9982	3.9976	4.9970
89	91	269	271	.9998	1.9996	2.9994	3.9992	4.9990
90	90	270	270	1.0000	2.0000	3.0000	4.0000	5.0000

Table 6 — Instantaneous Values of Voltage or Current of Sinusoids

Phase Angle (degrees)				Peak Voltage or Current				
				6	7	8	9	10
0	180	180	360	.0000	.0000	.0000	.0000	.0000
1	179	181	359	.1050	.1225	.1400	.1575	.1750
2	178	182	358	.2094	.2443	.2792	.3141	.3490
3	177	183	357	.3138	.3661	.4184	.4707	.5230
4	176	184	356	.4188	.4886	.5584	.6282	.6980
5	175	185	355	.5232	.6104	.6976	.7848	.8720
6	174	186	354	.6270	.7315	.8360	.9405	1.0450
7	173	187	353	.7314	.8533	.9752	1.0971	1.2190
8	172	188	352	.8352	.9744	1.1136	1.2528	1.3920
9	171	189	351	.9384	1.0948	1.2512	1.4076	1.5640
10	170	190	350	1.0416	1.2152	1.3888	1.5624	1.7360
11	169	191	349	1.4448	1.3356	1.5264	1.7172	1.9080
12	168	192	348	1.2474	1.4553	1.6632	1.8711	2.0790
13	167	193	347	1.3500	1.5750	1.8000	2.0250	2.2500
14	166	194	346	1.4514	1.6933	1.9352	2.1771	2.4190
15	165	195	345	1.5528	1.8116	2.0704	2.3292	2.5880
16	164	196	344	1.6536	1.9292	2.2048	2.4804	2.7560
17	163	197	343	1.7544	2.0468	2.3392	2.6316	2.9240
18	162	198	342	1.8540	2.1630	2.4720	2.7810	3.0900
19	161	199	341	1.9536	2.2792	2.6048	2.9304	3.2560
20	160	200	340	2.0520	2.3940	2.7360	3.0780	3.4200
21	159	201	339	2.1504	2.5088	2.8672	3.2256	3.5840
22	158	202	338	2.2476	2.6222	2.9968	3.3714	3.7460
23	157	203	337	2.3442	2.7349	3.1256	3.5163	3.9070
24	156	204	336	2.4402	2.8469	3.2536	3.6603	4.0670
25	155	205	335	2.5356	2.9582	3.3808	3.8034	4.2260
26	154	206	334	2.6304	3.0688	3.5072	3.9456	4.3840
27	153	207	333	2.7240	3.1780	3.6320	4.0860	4.5400
28	152	208	332	2.8170	3.2865	3.7560	4.2255	4.6950
29	151	209	331	2.9088	3.3936	3.8784	4.3632	4.8480
30	150	210	330	3.0000	3.5000	4.0000	4.5000	5.0000

Table 6 — Instantaneous Values of Voltage or Current of Sinusoids

Phase Angle (degrees)				Peak Voltage or Current 6	7	8	9	10
31	149	211	329	3.0900	3.6050	4.1200	4.6350	5.1500
32	148	212	328	3.1794	3.7093	4.2392	4.7691	5.2990
33	147	213	327	3.2676	3.8122	4.3568	4.9014	5.4460
34	146	214	326	3.3552	3.9144	4.4736	5.0328	5.5920
35	145	215	325	3.4416	4.0152	4.5888	5.1634	5.7360
36	144	216	324	3.5268	4.1146	4.7004	5.2902	5.8780
37	143	217	323	3.6108	4.2126	4.8144	5.4162	6.0180
38	142	218	322	3.6942	4.3099	4.9256	5.5413	6.1570
39	141	219	321	3.7758	4.4051	5.0344	5.6637	6.2930
40	140	220	320	3.8568	4.4996	5.1424	5.7852	6.4280
41	139	221	319	3.9366	4.5927	5.2488	5.9049	6.5610
42	138	222	318	4.0146	4.6837	5.3528	6.0219	6.6910
43	137	223	317	4.0920	4.7740	5.4560	6.1380	6.8200
44	136	224	316	4.1682	4.8629	5.5576	6.2523	6.9470
45	135	225	315	4.2426	4.9497	5.6568	6.3639	7.0710
46	134	226	314	4.3158	5.0351	5.7544	6.4737	7.1930
47	133	227	313	4.3884	5.1198	5.8512	6.5826	7.3140
48	132	228	312	4.4586	5.2017	5.9448	6.6879	7.4310
49	131	229	311	4.5282	5.2829	6.0376	6.7923	7.5470
50	130	230	310	4.5960	5.3620	6.1280	6.8940	7.6600
51	129	231	309	4.6626	5.4397	6.2168	6.9939	7.7710
52	128	232	308	4.7280	5.5160	6.3040	7.0920	7.8800
53	127	233	307	4.7916	5.5902	6.3888	7.1874	7.9860
54	126	234	306	4.8540	5.6630	6.4720	7.2810	8.0900
55	125	235	305	4.9152	5.7344	6.5536	7.3728	8.1920
56	124	236	304	4.9740	5.8030	6.6320	7.4610	8.2900
57	123	237	303	5.0322	5.8709	6.7096	7.5083	8.3870
58	122	238	302	5.0880	5.9360	6.7840	7.6320	8.4800
59	121	239	301	5.1432	6.0004	6.8576	7.7148	8.5720
60	120	240	300	5.1960	6.0620	6.9280	7.7940	8.6600

Table 6 — Instantaneous Values of Voltage or Current of Sinusoids

Phase Angle (degrees)				Peak Voltage or Current 6	7	8	9	10
61	119	241	299	5.2476	6.1222	6.9968	7.8714	8.7460
62	118	242	298	5.2974	6.1803	7.0632	7.9461	8.8290
63	117	243	297	5.3460	6.2370	7.1280	8.0190	8.9100
64	116	244	296	5.3928	6.2916	7.1904	8.0892	8.9880
65	115	245	295	5.4378	6.3441	7.2504	8.1567	9.0630
66	114	246	294	5.4810	6.3945	7.3080	8.2215	9.1350
67	113	247	293	5.5230	6.4435	7.3640	8.2845	9.2050
68	112	248	292	5.5632	6.4904	7.4176	8.3448	9.2720
69	111	249	291	5.6016	6.5352	7.4688	8.4024	9.3360
70	110	250	290	5.6382	6.5779	7.5176	8.4573	9.3970
71	109	251	289	5.6730	6.6185	7.5640	8.5095	9.4550
72	108	252	288	5.7066	6.6577	7.6088	8.5599	9.5110
73	107	253	287	5.7378	6.6941	7.6504	8.6067	9.5630
74	106	254	286	5.7678	6.7291	7.6904	8.6517	9.6120
75	105	255	285	5.7954	6.7613	7.7272	8.6931	9.6590
76	104	256	284	5.8218	6.7921	7.7624	8.7327	9.7030
77	103	257	283	5.8464	6.8208	7.7952	8.7696	9.7440
78	102	258	282	5.8686	6.8467	7.8248	8.8029	9.7810
79	101	259	281	5.8896	6.8712	7.8528	8.8344	9.8160
80	100	260	280	5.9088	6.8936	7.8784	8.8632	9.8480
81	99	261	279	5.9262	6.9139	7.9016	8.8893	9.8770
82	98	262	278	5.9418	6.9321	7.9224	8.9127	9.9030
83	97	263	277	5.9550	6.9475	7.9400	8.9325	9.9250
84	96	264	276	5.9670	6.9615	7.9560	8.9505	9.9450
85	95	265	275	5.9772	6.9734	7.9696	8.9658	9.9620
86	94	266	274	5.9856	6.9832	7.9808	8.9784	9.9760
87	93	267	273	5.9916	6.9902	7.9888	8.9874	9.9860
88	92	268	272	5.9964	6.9958	7.9952	8.9946	9.9940
89	91	269	271	5.9988	6.9986	7.9984	8.9982	9.9980
90	90	270	270	6.0000	7.0000	8.0000	9.0000	10.0000

Period and frequency

The time required for the completion of one complete cycle by a periodic function, such as a sine wave, is known as its period. The relationship between the period and the frequency of a wave is a reciprocal one and is shown in the formula $T = 1/f$. In this formula, T, the period of the wave, is the time required for the completion of one full cycle; f is the frequency in cycles per second.

Table 7 permits the rapid conversion between the period of a wave and its frequency. Values not given in the Table can be obtained by moving the decimal point. However, since the relationship is an inverse one, the decimal point for frequency and for time will move in opposite directions. Thus, for a frequency of 10 cycles, the time is 0.1 second. For a frequency of 100 cycles, we would move the decimal point one place to the right, thus changing 10 to 100. For the corresponding value of time, however, we would need to move the decimal point one place to the left. This would change 0.1 second to 0.01 second.

Examples:

The sine wave input to a power supply is 60 cps. What is the period of this wave?

Locate 60 in the *frequency* column. Immediately adjacent you will see that it requires .0167 second to complete one single cycle of this waveform.

What is the period of a sine waveform having a frequency of 550 kilocycles?

In Table 7 the frequency is given in cps. Thus, 55 in that Table can be made to represent 550 kc by multiplying it by 10^4 or by moving its decimal point four places to the right (550,000). However, as shown in the formula given above, T and f are inverse. Thus, if we move the decimal point to the right for the *frequency* column, we must move it to the left an equal number of places for the *time* column. For 55 cycles the time is .0182 second. For 550,000 cycles the time is .00000182 second or 1.82 μsec.

The time of a half wave is 61 microseconds. What is its frequency?

Assuming that the problem involves a sine wave, first multiply 61 by 2 to get the time of a full wave. $2 \times 61 = 122$. 122 microseconds corresponds to .000122 second. The nearest value shown in the Table is .0122 second, and the frequency for this time value is 82 cps. We can get .000122 by moving the decimal point of .0122 two places to the left. The decimal point for the frequency, then, should be moved an equivalent number of places to the right. This would give us our answer of 8,200 cps.

Table 7 — Period and Frequency

Frequency (cps)	Time (sec)	Frequency (cps)	Time (sec)	Frequency (cps)	Time (sec)
1	1.0000	34	.0294	67	.0149
2	.5000	35	.0286	68	.0147
3	.3333	36	.0278	69	.0145
4	.2500	37	.0270	70	.0143
5	.2000	38	.0263	71	.0141
6	.1667	39	.0256	72	.0139
7	.1429	40	.0250	73	.0137
8	.1250	41	.0244	74	.0135
9	.1111	42	.0238	75	.0133
10	.1000	43	.0233	76	.0132
11	.0909	44	.0227	77	.0130
12	.0833	45	.0222	78	.0128
13	.0769	46	.0217	79	.0127
14	.0714	47	.0213	80	.0125
15	.0667	48	.0208	81	.0123
16	.0625	49	.0204	82	.0122
17	.0588	50	.0200	83	.0120
18	.0556	51	.0196	84	.0119
19	.0526	52	.0192	85	.0118
20	.0500	53	.0189	86	.0116
21	.0476	54	.0185	87	.0115
22	.0455	55	.0182	88	.0114
23	.0435	56	.0179	89	.0112
24	.0417	57	.0175	90	.0111
25	.0400	58	.0172	91	.0110
26	.0385	59	.0169	92	.0109
27	.0370	60	.0167	93	.0108
28	.0357	61	.0164	94	.0106
29	.0345	62	.0161	95	.0105
30	.0333	63	.0159	96	.0104
31	.0323	64	.0156	97	.0103
32	.0312	65	.0154	98	.0102
33	.0303	66	.0152	99	.0101
				100	.0100

Frequency-wavelength conversion (kilocycles-meters)

The relationship between the frequency of a wave, in cycles per second and its wavelength, in meters, is supplied by the formula $\lambda = 300{,}000{,}000/f$. The number 300,000,000 in the numerator of the formula is the velocity of light (and of radio waves) in space, and is a constant. λ is the wavelength in meters.

Table 8 supplies the abbreviations and description of waves whose frequency extends from below 30 kilocycles to 300,000 megacycles.

Table 9 supplies conversion data between frequency in kilocycles and wavelength in meters. The columns shown in the Table are interchangeable and cover the range from 10 kilocycles or meters to 10,000 kilocycles or meters.

Table 8 — Frequency Bands

Frequency	*Description*	*Abbreviation*
Below 30 kc	very-low frequency	VLF
30 to 300 kc	low frequency	LF
300 to 3,000 kc	medium frequency	MF
3,000 to 30,000 kc	high frequency	HF
30 to 300 mc	very-high frequency	VHF
300 to 3,000 mc	ultra-high frequency	UHF
3,000 to 30,000 mc	super-high frequency	SHF
30,000 to 300,000 mc (30 gc to 300 gc)	extremely-high frequency	EHF

Examples:

A radio wave has a frequency of 500 kilocycles. What is its wavelength in meters?

Find the number 500 in Table 9. Move horizontally and you will see the corresponding wavelength of 599.6 meters.

One of the bands of a short-wave receiver covers the range from 3,000 kc to 5,000 kc. What wavelength range does this include?

The Table shows that 3,000 kc corresponds to 99.94 meters and that 5,000 kc corresponds to 59.96 meters. Thus, this particular band is from approximately 60 to 100 meters.

What is the length, in feet, of a wave having a frequency of 4,283 kilocycles?

Locate this frequency (4,283 kc) in the *kc* column. You will note that it corresponds to a wavelength of 70 meters. However, the problem calls for the answer in feet. Consult Table 11 on page 43 and you will see that 70 meters is between 21 and 22 feet.

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
10	29,982	310	967.2	610	491.5
20	14,991	320	967.9	620	483.6
30	9,994	330	908.6	630	475.9
40	7,496	340	881.8	640	468.5
50	5,996	350	856.6	650	461.3
60	4,997	360	832.8	660	454.3
70	4,283	370	810.3	670	447.5
80	3,748	380	789.0	680	440.9
90	3,331	390	768.8	690	434.5
100	2,998	400	749.6	700	428.3
110	2,726	410	731.3	710	422.3
120	3,499	420	713.9	720	416.4
130	2,306	430	697.3	730	410.7
140	2,142	440	681.4	740	405.2
150	1,999	450	666.3	750	399.8
160	1,874	460	651.8	760	394.5
170	1,764	470	637.9	770	389.4
180	1,666	480	624.6	780	384.4
190	1,578	490	611.9	790	379.5
200	1,499	500	599.6	800	374.8
210	1,428	510	587.9	810	370.2
220	1,363	520	576.6	820	365.6
230	1,304	530	565.7	830	361.2
240	1,249	540	555.2	840	356.9
250	1,199	550	545.1	850	352.7
260	1,153	560	535.4	860	348.6
270	1,110	570	526.0	870	344.6
280	1,071	580	516.9	880	340.7
290	1,034	590	508.2	890	336.9
300	999.4	600	499.7	900	333.1

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	m or kc	kc or m	m or kc	kc or m	m or kc
910	329.5	1,210	247.8	1,510	198.6
920	325.9	1,220	245.8	1,520	197.2
930	322.4	1,230	243.8	1,530	196.0
940	319.0	1,240	241.8	1,540	194.7
950	315.6	1,250	239.9	1,550	193.4
960	312.3	1,260	238.0	1,560	192.2
970	309.1	1,270	236.1	1,570	191.0
980	303.9	1,280	234.2	1,580	189.8
990	302.8	1,290	232.4	1,590	188.6
1,000	299.8	1,300	230.6	1,600	187.4
1,010	296.9	1,310	228.9	1,610	186.2
1,020	293.9	1,320	227.1	1,620	185.1
1,030	291.1	1,330	225.4	1,630	183.9
1,040	288.3	1,340	223.7	1,640	182.8
1,050	285.5	1,350	222.1	1,650	181.7
1,060	282.8	1,360	220.4	1,660	180.6
1,070	280.2	1,370	218.8	1,670	179.5
1,080	277.6	1,380	217.3	1,680	178.5
1,090	275.1	1,390	215.7	1,690	177.4
1,100	272.6	1,400	214.2	1,700	176.4
1,110	270.1	1,410	212.6	1,710	175.3
1,120	267.7	1,420	211.1	1,720	174.3
1,130	265.3	1,430	209.7	1,730	173.3
1,140	263.0	1,440	208.2	1,740	172.3
1,150	260.7	1,450	206.8	1,750	171.3
1,160	258.5	1,460	205.4	1,760	170.4
1,170	256.3	1,470	204.0	1,770	169.4
1,180	254.1	1,480	202.6	1,780	168.4
1,190	252.0	1,490	201.2	1,790	167.5
1,200	249.9	1,500	199.9	1,800	166.6

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
1,810	165.6	2,110	142.1	2,410	124.4
1,820	164.7	2,120	141.4	2,420	123.9
1,830	163.8	2,130	140.8	2,430	123.4
1,840	162.9	2,140	140.1	2,440	122.9
1,850	162.1	2,150	139.5	2,450	122.4
1,860	161.2	2,160	138.8	2,460	121.9
1,870	160.3	2,170	138.1	2,470	121.4
1,880	159.5	2,180	137.5	2,480	120.9
1,890	158.6	2,190	136.9	2,490	120.4
1,900	157.8	2,200	136.3	2,500	119.9
1,910	157.0	2,210	135.7	2,510	119.5
1,920	156.2	2,220	135.1	2,520	119.0
1,930	155.3	2,230	134.4	2,530	118.5
1,940	154.5	2,240	133.8	2,540	118.0
1,950	153.8	2,250	133.3	2,550	117.6
1,960	153.0	2,260	132.7	2,560	117.1
1,970	152.2	2,270	132.1	2,570	116.7
1,980	151.4	2,280	131.5	2,580	116.2
1,990	150.7	2,290	130.9	2,590	115.8
2,000	149.9	2,300	130.4	2,600	115.3
2,010	149.2	2,310	129.8	2,610	114.9
2,020	148.4	2,320	129.2	2,620	114.4
2,030	147.7	2,330	128.7	2,630	114.0
2,040	147.0	2,340	128.1	2,640	113.6
2,050	146.3	2,350	127.6	2,650	113.1
2,060	145.5	2,360	127.0	2,660	112.7
2,070	144.8	2,370	126.5	2,670	112.3
2,080	144.1	2,380	126.0	2,680	111.9
2,090	143.5	2,390	125.4	2,690	111.5
2,100	142.8	2,400	124.9	2,700	111.0

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
2,710	110.6	3,010	99.61	3,310	90.58
2,720	110.2	3,020	99.28	3,320	90.31
2,730	109.8	3,030	98.95	3,330	90.04
2,740	109.4	3,040	98.62	3,340	89.77
2,750	109.0	3,050	98.30	3,350	89.50
2,760	108.6	3,060	97.98	3,360	89.23
2,770	108.2	3,070	97.66	3,370	88.97
2,780	107.8	3,080	97.34	3,380	88.70
2,790	107.5	3,090	97.03	3,390	88.44
2,800	107.1	3,100	96.72	3,400	88.18
2,810	106.7	3,110	96.41	3,410	87.92
2,820	106.3	3,120	96.10	3,420	87.67
2,830	105.9	3,130	95.79	3,430	87.41
2,840	105.6	3,140	95.48	3,440	87.16
2,850	105.2	3,150	95.18	3,450	86.90
2,860	104.8	3,160	94.88	3,460	96.65
2,870	104.5	3,170	94.58	3,470	86.40
2,880	104.1	3,180	94.28	3,480	86.16
2,890	103.7	3,190	93.99	3,490	85.91
2,900	103.4	3,200	93.69	3,500	85.66
2,910	103.0	3,210	93.40	3,510	85.42
2,920	102.7	3,220	93.11	3,520	85.18
2,930	102.3	3,230	92.82	3,530	84.94
2,940	102.0	3,240	92.54	3,540	84.70
2,950	101.6	3,250	92.25	3,550	84.46
2,960	101.3	3,260	91.97	3,560	84.22
2,970	100.9	3,270	91.69	3,570	83.98
2,980	100.6	3,280	91.41	3,580	83.75
2,990	100.3	3,290	91.13	3,590	83.52
3,000	99.94	3,300	90.86	3,600	83.28

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
3,610	83.05	3,910	76.68	4,210	71.22
3,620	82.82	3,920	76.48	4,220	71.05
3,630	82.60	3,930	76.29	4,230	70.88
3,640	82.37	3,940	76.10	4,240	70.71
3,650	82.14	3,950	75.90	4,250	70.55
3,660	81.92	3,960	75.51	4,260	70.38
3,670	81.70	3,970	75.52	4,270	70.22
3,680	81.47	3,980	75.33	4,280	70.05
3,690	81.25	3,990	75.14	4,290	69.89
3,700	81.03	4,000	74.96	4,300	69.73
3,710	80.81	4,010	74.77	4,310	69.56
3,720	80.60	4,020	74.58	4,320	69.40
3,730	80.38	4,030	74.40	4,330	69.24
3,740	80.17	4,040	74.21	4,340	69.08
3,750	79.95	4,050	74.03	4,350	68.92
3,760	79.74	4,060	73.85	4,360	68.77
3,770	79.53	4,070	73.67	4,370	68.61
3,780	79.32	4,080	73.49	4,380	68.45
3,790	79.11	4,090	73.31	4,390	68.30
3,800	78.90	4,100	73.13	4,400	68.14
3,810	78.69	4,110	72.95	4,410	67.99
3,820	78.49	4,120	72.77	4,420	67.83
3,830	78.28	4,130	72.60	4,430	67.68
3,840	78.08	4,140	72.42	4,440	67.53
3,850	77.88	4,150	72.25	4,450	67.38
3,860	77.67	4,160	72.07	4,460	67.22
3,870	77.47	4,170	71.90	4,470	67.07
3,880	77.27	4,180	71.73	4,480	66.92
3,890	77.07	4,190	71.56	4,490	66.78
3,900	76.88	4,200	71.30	4,500	66.63

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
4,510	66.48	4,810	62.33	5,110	58.67
4,520	66.33	4,820	62.20	5,120	58.56
4,530	66.19	4,830	62.07	5,130	58.44
4,540	66.04	4,840	61.95	5,140	58.33
4,550	65.89	4,850	61.82	5,150	58.22
4,560	65.75	4,860	61.69	5,160	58.10
4,570	65.61	4,870	61.56	5,170	57.99
4,580	65.46	4,880	61.44	5,180	57.88
4,590	65.32	4,890	61.31	5,190	57.77
4,600	65.18	4,900	61.19	5,200	57.66
4,610	65.04	4,910	61.06	5,210	57.55
4,620	64.90	4,920	60.94	5,220	57.44
4,630	64.76	4,930	60.82	5,230	57.33
4,640	64.62	4,940	60.69	5,240	57.22
4,650	64.48	4,950	60.57	5,250	57.11
4,660	64.34	4,960	60.45	5,260	57.00
4,670	64.20	4,970	60.33	5,270	56.89
4,680	64.06	4,980	60.20	5,280	56.78
4,690	63.93	4,990	60.08	5,290	56.68
4,700	63.79	5,000	59.96	5,300	56.57
4,710	63.66	5,010	59.84	5,310	56.46
4,720	63.52	5,020	59.73	5,320	56.36
4,730	63.39	5,030	59.61	5,330	56.25
4,740	63.25	5,040	59.49	5,340	56.15
4,750	63.12	5,050	59.37	5,350	56.04
4,760	62.99	5,060	59.25	5,360	55.94
4,770	62.86	5,070	59.13	5,370	55.88
4,780	62.72	5,080	59.02	5,380	55.73
4,790	62.59	5,090	58.90	5,390	55.63
4,800	62.46	5,100	58.79	5,400	55.52

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
5,410	55.42	5,710	52.51	6,010	49.89
5,420	55.32	5,720	52.42	6,020	49.80
5,430	55.22	5,730	52.32	6,030	49.72
5,440	55.11	5,740	52.23	6,040	49.64
5,450	55.01	5,750	52.14	6,050	49.56
5,460	54.91	5,760	52.05	6,060	49.48
5,470	54.81	5,770	51.96	6,070	49.39
5,480	54.71	5,780	51.87	6,080	49.31
5,490	54.61	5,790	51.78	6,090	49.23
5,500	54.51	5,800	51.69	6,100	49.15
5,510	54.41	5,810	51.60	6,110	49.07
5,520	54.32	5,820	52.52	6,120	48.99
5,530	54.22	5,830	51.43	6,130	48.91
5,540	54.12	5,840	51.34	6,140	48.83
5,550	54.02	5,850	51.25	6,150	48.75
5,560	53.92	5,860	51.16	6,160	48.67
5,570	53.83	5,870	51.08	6,170	48.59
5,580	53.73	5,880	50.99	6,180	48.51
5,590	53.64	5,890	50.90	6,190	48.44
5,600	53.54	5,900	50.82	6,200	48.36
5,610	53.44	5,910	50.73	6,210	48.28
5,620	53.35	5,920	50.65	6,220	48.20
5,630	53.25	5,930	50.56	6,230	48.13
5,640	53.16	5,940	50.47	6,240	48.05
5,650	53.07	5,950	50.39	6,250	47.97
5,660	52.97	5,960	50.31	6,260	47.89
5,670	52.88	5,970	50.22	6,270	47.82
5,680	52.79	5,980	50.14	6,280	47.74
5,690	52.69	5,990	50.05	6,290	47.67
5,700	52.60	6,000	49.97	6,300	47.59

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
6,310	47.52	6,610	45.36	6,910	43.39
6,320	47.44	6,620	45.29	6,920	43.33
6,330	47.36	6,630	45.22	6,930	43.26
6,340	47.29	6,640	45.15	6,940	43.20
6,350	47.22	6,650	45.09	6,950	43.14
6,360	47.14	6,660	45.02	6,960	43.08
6,370	47.07	6,670	44.95	6,970	43.02
6,380	46.99	6,680	44.88	6,980	42.95
6,390	46.92	6,690	44.82	6,990	42.89
6,400	46.85	6,700	44.75	7,000	42.83
6,410	46.77	6,710	44.68	7,010	42.77
6,420	46.70	6,720	44.62	7,020	42.71
6,430	46.63	6,730	44.55	7,030	42.65
6,440	46.56	6,740	44.48	7,040	42.59
6,450	46.48	6,750	44.42	7,050	42.53
6,460	46.41	6,760	44.35	7,060	42.47
6,470	46.34	6,770	44.29	7,070	42.41
6,480	46.27	6,780	44.22	7,080	42.35
6,490	46.20	6,790	44.16	7,090	42.29
6,500	46.13	6,800	44.09	7,100	42.23
6,510	46.06	6,810	44.03	7,110	42.17
6,520	45.98	6,820	43.96	7,120	42.11
6,530	45.91	6,830	43.90	7,130	42.05
6,540	45.84	6,840	43.83	7,140	41.99
6,550	45.77	6,850	43.77	7,150	41.93
6,560	45.70	6,860	43.71	7,160	41.87
6,570	45.63	6,870	43.64	7,170	41.82
6,580	45.57	6,880	43.58	7,180	41.76
6,590	45.50	6,890	43.52	7,190	41.70
6,600	45.43	6,900	43.45	7,200	41.64

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
7,210	41.58	7,510	39.92	7,810	38.39
7,220	41.53	7,520	39.87	7,820	38.34
7,230	41.47	7,530	39.82	7,830	38.29
7,240	41.41	7,540	39.76	7,840	38.24
7,250	41.35	7,550	39.71	7,850	38.19
7,260	41.30	7,560	39.66	7,860	38.14
7,270	41.24	7,570	39.61	7,870	38.10
7,280	41.18	7,580	39.55	7,880	38.05
7,290	41.13	7,590	39.50	7,890	38.00
7,300	41.07	7,600	39.45	7,900	37.95
7,310	41.02	7,610	39.40	7,910	37.90
7,320	40.96	7,620	39.35	7,920	37.86
7,330	40.90	7,630	39.29	7,930	37.81
7,340	40.85	7,640	39.24	7,940	37.76
7,350	40.79	7,650	39.19	7,950	37.71
7,360	40.74	7,660	39.14	7,960	37.67
7,370	40.68	7,670	39.09	7,970	37.62
7,380	40.63	7,680	39.04	7,980	37.57
7,390	40.57	7,690	38.99	7,990	37.52
7,400	40.52	7,700	38.04	8,000	37.48
7,410	40.46	7,710	38.89	8,010	37.43
7,420	40.41	7,720	38.84	8,020	37.38
7,430	40.35	7,730	38.79	8,030	37.34
7,440	40.30	7,740	38.74	8,040	37.29
7,450	40.24	7,750	38.69	8,050	37.24
7,460	40.10	7,760	38.64	8,060	37.20
7,470	40.14	7,770	38.59	8,070	37.15
7,480	40.08	7,780	38.54	8,080	37.11
7,490	40.03	7,790	38.49	8,090	37.06
7,500	39.98	7,800	38.44	8,100	37.01

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
8,110	36.97	8,410	35.65	8,710	34.42
8,120	36.92	8,420	35.61	8,720	34.38
8,130	36.88	8,430	35.57	8,730	34.34
8,140	36.83	8,440	35.52	8,740	34.30
8,150	36.79	8,450	35.48	8,750	34.27
8,160	36.74	8,460	35.44	8,760	34.23
8,170	36.70	8,470	35.40	8,770	34.19
8,180	36.65	8,480	35.36	8,780	34.15
8,190	36.61	8,490	35.31	8,790	34.11
8,200	36.56	8,500	35.27	8,800	34.07
8,210	36.52	8,510	35.23	8,810	34.03
8,220	36.47	8,520	35.19	8,820	33.99
8,230	36.43	8,530	35.15	8,830	33.95
8,240	36.39	8,540	35.11	8,840	33.92
8,250	36.34	8,550	35.07	8,850	33.88
8,260	36.30	8,560	35.03	8,860	33.84
8,270	36.25	8,570	34.98	8,870	33.80
8,280	36.21	8,580	34.94	8,880	33.76
8,290	36.17	8,590	34.90	8,890	33.73
8,300	36.12	8,600	34.86	8,900	33.69
8,310	36.08	8,610	34.82	8,910	33.65
8,320	36.04	8,620	34.78	8,920	33.61
8,330	35.99	8,630	34.74	8,930	33.57
8,340	35.95	8,640	34.70	8,940	33.54
8,350	35.91	8,650	34.66	8,950	33.50
8,360	35.86	8,660	34.62	8,960	33.46
8,370	35.82	8,670	34.58	8,970	33.42
8,380	35.78	8,680	34.54	8,980	33.39
8,390	35.74	8,690	34.50	8,990	33.35
8,400	35.69	8,700	34.46	9,000	33.31

Table 9 — Kilocycles (kc) to Meters (m), or Meters to Kilocycles

[Columns Are Interchangeable]

kc or m	*m or kc*	*kc or m*	*m or kc*	*kc or m*	*m or kc*
9,010	33.28	9,340	32.10	9,670	31.01
9,020	33.24	9,350	32.07	9,680	30.97
9,030	33.20	9,360	32.03	9,690	30.94
9,040	33.17	9,370	32.00	9,700	30.91
9,050	33.13	9,380	31.96	9,710	30.88
9,060	33.09	9,390	31.93	9,720	30.85
9,070	33.06	9,400	31.90	9,730	30.81
9,080	33.02	9,410	31.86	9,740	30.78
9,090	32.98	9,420	31.83	9,750	30.75
9,100	32.95	9,430	31.79	9,760	30.72
9,110	32.91	9,440	31.76	9,770	30.69
9,120	32.88	9,450	31.73	9,780	30.66
9,130	32.84	9,460	31.69	9,790	30.63
9,140	32.80	9,470	31.66	9,800	30.59
9,150	32.77	9,480	31.63	9,810	30.56
9,160	32.73	9,490	31.59	9,820	30.53
9,170	32.70	9,500	31.56	9,830	30.50
9,180	32.66	9,510	31.53	9,840	30.47
9,190	32.62	9,520	31.49	9,850	30.44
9,200	32.59	9,530	31.46	9,860	30.41
9,210	32.55	9,540	31.43	9,870	30.38
9,220	32.52	9,550	31.39	9,880	30.35
9,230	32.48	9,560	31.36	9,890	30.32
9,240	32.45	9,570	31.33	9,900	30.28
9,250	32.41	9,580	31.30	9,910	30.25
9,260	32.38	9,590	31.26	9,920	30.22
9,270	32.34	9,600	31.23	9,930	30.19
9,280	32.31	9,610	31.20	9,940	30.16
9,290	32.27	9,620	31.17	9,950	30.13
9,300	32.24	9,630	31.13	9,960	30.10
9,310	32.20	9,640	31.10	9,970	30.07
9,320	32.17	9,650	31.07	9,980	30.04
9,330	32.14	9,660	31.04	9,990	30.01
				10,000	29.98

Conversion — feet to meters and meters to feet

The distance from the start to the finish of a single cycle of a wave, called the wavelength, is usually specified in meters. And the relationship between frequency and wavelength is always one in which wavelength is in meters. However, we may be more accustomed to the units of linear measure as shown in Table 10.

Table 11 supplies the data on the conversion of meters to feet or feet to meters. The Table can easily be extended by moving the decimal point. Be sure to move the decimal point an equal number of places in the same direction in both columns. Thus, 18 feet, corresponding to a wavelength of 59.04 meters could be 180 feet and 590.4 meters, or 1,800 feet and 5,904 meters.

Table 10 — Linear Measure

12 inches = 1 foot
3 feet = 1 yard = 36 inches
5½ yards = 1 rod or pole = 16½ feet
40 rods = 1 furlong = 220 yards = 660 feet = ⅛ mile
8 furlongs = 1 statute mile = 1760 yards = 5280 feet
3 miles = 1 league = 5280 yards = 15,840 feet

Examples:

What is the length, in feet, of a wave that is 36 meters long?
The nearest value to 36 meters in Table 11 is 36.08 meters. The corresponding distance is 11 feet.

What is the frequency of a wave whose wavelength is 20 feet?
This question requires the use of two tables. Table 11 shows that 20 feet corresponds to 65.60 meters. Now turn to Table 9 on page 36. The nearest wavelength is 65.61 meters, and, as shown, the frequency is 4,570 kilocycles.

Table 11 — Feet to Meters or Meters to Feet

Feet	Meters	Feet	Meters	Feet	Meters
1	3.28	34	111.52	67	219.76
2	6.56	35	114.80	68	223.04
3	9.84	36	118.08	69	226.32
4	13.12	37	121.36	70	229.60
5	16.40	38	124.64	71	232.88
6	19.68	39	127.92	72	236.16
7	22.96	40	131.20	73	239.44
8	26.24	41	134.48	74	242.72
9	29.52	42	137.76	75	246.00
10	32.80	43	141.04	76	249.28
11	36.08	44	144.32	77	252.56
12	39.36	45	147.60	78	255.84
13	42.64	46	150.88	79	259.12
14	45.92	47	154.16	80	262.40
15	49.20	48	157.44	81	265.68
16	52.48	49	160.72	82	268.96
17	55.76	50	164.00	83	272.24
18	59.04	51	167.28	84	275.52
19	62.32	52	170.56	85	278.80
20	65.60	53	173.84	86	282.08
21	68.88	54	177.12	87	285.36
22	72.16	55	180.40	88	288.64
23	75.44	56	183.68	89	291.92
24	78.72	57	186.96	90	295.20
25	82.00	58	190.24	91	298.48
26	85.28	59	193.52	92	301.76
27	88.56	60	196.80	93	305.04
28	91.84	61	200.08	94	308.32
29	95.12	62	203.36	95	311.60
30	98.40	63	206.64	96	314.88
31	101.68	64	209.92	97	318.16
32	104.96	65	213.20	98	321.44
33	108.24	66	216.48	99	324.72
				100	328.00

Conversion — inches to millimeters and millimeters to inches

Table 12 on page 45 supplies a convenient way of converting inches to millimeters. Use Table 13 on page 46 for converting millimeters to inches. The range of both Tables can easily be extended by moving the decimal point an equal number of places in the same direction, for both columns.

Tables 12 and 13 are based on these fundamental relationships between units of measure in the metric system and units of linear measurement.

1 inch = 2.54 cm
1 inch = 25.40 mm
1 inch = .0254 meter
1 foot = 304.80 mm
1 foot = 30.48 cm
1 cm = 0.3936 inch
1 cm = .03280 foot
1 mm = .0393 inch
1 mm = .00328 foot
1 meter = 39.3696 inches
1 meter = 3.2808 feet

Examples:

What is the length in millimeters of a wave whose length is 0.280 inch?

Locate 0.280 in the inches column in Table 12. The answer, 7.11 millimeters is shown in the column immediately to the right.

A wave is approximately 33 millimeters long. What is its length in inches?

Locate 3.302 in the millimeters column in Table 12. By moving the decimal point one place to the right, you will have 33.02 millimeters. The corresponding distance in inches is 0.130, but we must move the decimal point one place to the right. Our answer, then, is 1.30 inches.

A wave has a length of 0.92 millimeter. What is the corresponding length in inches ?

Using Table 13 on page 46 locate 0.92 in the millimeters column. You will see that the length in inches is 0.0362.

Table 12 — Inches to Millimeters

Inches	*Milli-meters*	*Inches*	*Milli-meters*	*Inches*	*Milli-meters*
0.001	0.025	0.290	7.37	0.660	16.76
0.002	0.051	0.300	7.62	0.670	17.02
0.003	0.076	0.310	7.87	0.680	17.27
0.004	0.102	0.320	8.13	0.690	17.53
0.005	0.127	0.330	8.38	0.700	17.78
0.006	0.152	0.340	8.64	0.710	18.03
0.007	0.178	0.350	8.89	0.720	18.29
0.008	0.203	0.360	9.14	0.730	18.54
0.009	0.229	0.370	9.40	0.740	18.80
0.010	0.254	0.380	9.65	0.750	19.05
0.020	0.508	0.390	9.91	0.760	19.30
0.030	0.762	0.400	10.16	0.770	19.56
0.040	1.016	0.410	10.41	0.780	19.81
0.050	1.270	0.420	10.67	0.790	20.07
0.060	1.524	0.430	10.92	0.800	20.32
0.070	1.778	0.440	11.18	0.810	20.57
0.080	2.032	0.450	11.43	0.820	20.83
0.090	2.286	0.460	11.68	0.830	21.08
0.100	2.540	0.470	11.94	0.840	21.34
0.110	2.794	0.480	12.19	0.850	21.59
0.120	3.048	0.490	12.45	0.860	21.84
0.130	3.302	0.500	12.70	0.870	22.10
0.140	3.56	0.510	12.95	0.880	22.35
0.150	3.81	0.520	13.21	0.890	22.61
0.160	4.06	0.530	13.46	0.900	22.86
0.170	4.32	0.540	13.72	0.910	23.11
0.180	4.57	0.550	13.97	0.920	23.37
0.190	4.83	0.560	14.22	0.930	23.62
0.200	5.08	0.570	14.48	0.940	23.88
0.210	5.33	0.580	14.73	0.950	24.13
0.220	5.59	0.590	14.99	0.960	24.38
0.230	5.84	0.600	15.24	0.970	24.64
0.240	6.10	0.610	15.49	0.980	24.89
0.250	6.35	0.620	15.75	0.990	25.15
0.260	6.60	0.630	16.00	1.000	25.40
0.270	6.86	0.640	16.26	....	....
0.280	7.11	0.650	16.51	....	....

Table 13 — Millimeters to Inches

Milli-meters	*Inches*	*Milli-meters*	*Inches*	*Milli-meters*	*Inches*
0.01	0.0004	0.35	0.0138	0.68	0.0268
0.02	0.0008	0.36	0.0142	0.69	0.0272
0.03	0.0012	0.37	0.0146	0.70	0.0276
0.04	0.0016	0.38	0.0150	0.71	0.0280
0.05	0.0020	0.39	0.0154	0.72	0.0283
0.06	0.0024	0.40	0.0157	0.73	0.0287
0.07	0.0028	0.41	0.0161	0.74	0.0291
0.08	0.0031	0.42	0.0165	0.75	0.0295
0.09	0.0035	0.43	0.0169	0.76	0.0299
0.10	0.0039	0.44	0.0173	0.77	0.0303
0.11	0.0043	0.45	0.0177	0.78	0.0307
0.12	0.0047	0.46	0.0181	0.79	0.0311
0.13	0.0051	0.47	0.0185	0.80	0.0315
0.14	0.0055	0.48	0.0189	0.81	0.0319
0.15	0.0059	0.49	0.0193	0.82	0.0323
0.16	0.0063	0.50	0.0197	0.83	0.0327
0.17	0.0067	0.51	0.0201	0.84	0.0331
0.18	0.0071	0.52	0.0205	0.85	0.0335
0.19	0.0075	0.53	0.0209	0.86	0.0339
0.20	0.0079	0.54	0.0213	0.87	0.0343
0.21	0.0083	0.55	0.0217	0.88	0.0346
0.22	0.0087	0.56	0.0220	0.89	0.0350
0.23	0.0091	0.57	0.0224	0.90	0.0354
0.24	0.0094	0.58	0.0228	0.91	0.0358
0.25	0.0098	0.59	0.0232	0.92	0.0362
0.26	0.0102	0.60	0.0236	0.93	0.0366
0.27	0.0106	0.61	0.0240	0.94	0.0370
0.28	0.0110	0.62	0.0244	0.95	0.0374
0.29	0.0114	0.63	0.0248	0.96	0.0378
0.30	0.0118	0.64	0.0252	0.97	0.0382
0.31	0.0122	0.65	0.0256	0.98	0.0386
0.32	0.0126	0.66	0.0260	0.99	0.0390
0.33	0.0130	0.67	0.0264	1.00	0.0394
0.34	0.0134	. . .	. . . . .	. . .	. . . . .

Frequency-wavelength conversion for very-high frequencies

At very high frequencies certain components, such as the elements of receiving or transmitting antennas, become small enough to be measured easily. Knowing the frequency at which such elements work and using data such as that contained in Table 14 makes it easy to convert frequency into lengths in meters or centimeters.

In Table 14, λ represents the wavelength in centimeters or meters; mc is the frequency in megacycles.

Examples:

What is the frequency of a wave whose length is 10 cm?

Using Table 14 on this page find the number 10 under the heading of *cm*. As you move to the right you will note that this is also listed as 0.1 meter or one-tenth of a meter. Continue moving to the right and locate your answer in the *mc* column — 3,000 mc.

What is the wavelength of a wave whose frequency is 25 mc?

In the *mc* column in Table 14 on page 48 you will see 25.0 Move to the left and you will see that the corresponding wavelength is 12 meters.

Table 14 — Wavelength-Frequency Conversion (Very High Frequencies)

λ			λ		λ	
cm	*m*	*mc*	*m*	*mc*	*m*	*mc*
10	0.1	3,000	4.1	73.1	8.1	37.0
20	0.2	1,500	4.2	71.4	8.2	36.6
30	0.3	1,000	4.3	69.7	8.3	36.1
40	0.4	745	4.4	68.1	8.4	35.7
50	0.5	600	4.5	66.6	8.5	35.3
60	0.6	500	4.6	65.2	8.6	34.7
70	0.7	429	4.7	63.8	8.7	34.5
80	0.8	375	4.8	62.5	8.8	34.1
90	0.9	333	4.9	61.2	8.9	33.7
	1.0	300	5.0	60.0	9.0	33.3

Table 14 — Wavelength-Frequency Conversion (Very High Frequencies)

λ			λ		λ	
cm	m	mc	m	mc	m	mc
	1.1	273	5.1	58.8	9.1	33.0
	1.2	250	5.2	57.7	9.2	32.6
	1.3	231	5.3	56.6	9.3	32.2
	1.4	214	5.4	55.5	9.4	31.9
	1.5	200	5.5	54.5	9.5	31.6
	1.6	187	5.6	53.5	9.6	31.2
	1.7	176	5.7	52.6	9.7	31.0
	1.8	167	5.8	51.7	9.8	30.4
	1.9	158	5.9	50.8	9.9	30.1
	2.0	150	6.0	50.0	10.0	30.0
	2.1	143	6.1	49.2	10.1	29.7
	2.2	136	6.2	48.4	10.2	29.4
	2.3	130	6.3	47.6	10.3	29.1
	2.4	125	6.4	46.9	10.4	28.8
	2.5	120	6.5	46.1	10.5	28.6
	2.6	115	6.6	45.4	10.6	28.3
	2.7	111	6.7	44.8	10.7	28.0
	2.8	107	6.8	44.1	10.8	27.8
	2.9	103	6.9	43.5	10.9	27.5
	3.0	100	7.0	42.9	11.0	27.3
	3.1	96.7	7.1	42.2	11.1	27.0
	3.2	93.7	7.2	41.6	11.2	26.8
	3.3	90.9	7.3	41.1	11.3	26.5
	3.4	88.2	7.4	40.5	11.4	26.3
	3.5	85.7	7.5	40.0	11.5	26.1
	3.6	83.3	7.6	39.5	11.6	25.9
	3.7	81.0	7.7	38.9	11.7	25.6
	3.8	78.9	7.8	38.4	11.8	25.4
	3.9	76.9	7.9	38.0	11.9	25.2
	4.0	75.0	8.0	37.5	12.0	25.0

cm = centimeters; m = meters; mc = megacycles

Wavelengths of sound

The distance between two successive positive peaks, two successive negative peaks, or between any two corresponding points of a sine wave is known as its wavelength. As mentioned earlier, this is often represented by the letter λ. This description is not only applicable to radio-frequency waves, but also to sound waves. The reference here is not to a complex sound waveform, but to a pure sine wave only.

A sound wave of constant velocity (represented by the letter u) will travel a distance of one wavelength in a one period interval. This is more concisely stated in the formula $u = \lambda/T$. But the period of a wave has an inverse relationship to the frequency (see page 28). Thus, $T = 1/f$. By substituting in the formula $u = \lambda/T$, we get $u = f\lambda$. We can rearrange this formula to read $\lambda = u/f$.

The velocity of sound in air at a temperature of 0°C (68°F) is 1130 feet per second. Using this information, we can conveniently set up Table 15 on page 50 which gives the relationship between the frequency of sound in air in cycles per second and the wavelengths of sound in feet and in inches.

Conversion can be made by using Table 11 on page 43.

Examples:

What is the wavelength, in feet, of a 60-cycle sine wave?

Locate the number 60 in the left-hand column of Table 15 on page 50. The corresponding value is shown as 18.83.

A sound wave has a length of 7 feet. What is its frequency in cycles per second?

The closest value given in Table 15 is 7.01 feet. The frequency of this sound wave, then, is approximately 160 cps.

What is the wavelength, in meters, of a wave whose frequency is 75 cps?

First, locate the wavelength in feet corresponding to a frequency of 75 cps. Table 15 shows that this is 15.06 feet. Turn to page 43 and consult Table 11. The closest value to 15.06 is 15, as shown in the left-hand column. Move one column to the right and your answer is approximately 49.2 meters.

Table 15 — Wavelengths of Sound

Frequency (cps)	Wavelength (feet)	Frequency (cps)	Wavelength (feet)	Frequency (cps)	Wavelength (feet)
20	56.50	140	8.07	380	2.97
25	45.20	150	7.53	400	2.83
30	37.66	160	7.01	420	2.66
35	32.28	170	6.64	440	2.57
40	28.25	180	6.27	460	2.45
45	25.11	190	5.94	480	2.35
50	22.60	200	5.65	500	2.26
55	20.54	210	5.33	525	2.15
60	18.83	220	5.13	550	2.05
65	17.38	230	4.91	575	1.96
70	16.14	240	4.71	600	1.88
75	15.06	250	4.52	650	1.74
80	14.13	260	4.34	700	1.61
85	13.29	270	4.18	750	1.51
90	12.55	280	4.03	800	1.41
95	11.89	290	3.89	850	1.33
100	11.30	300	3.77	900	1.26
110	10.27	320	3.53	950	1.19
120	9.42	340	3.32	975	1.15
130	8.69	360	3.14	990	1.14

Frequency (cps)	Wavelength (inches)	Frequency (cps)	Wavelength (inches)	Frequency (cps)	Wavelength (inches)
1000	13.56	9000	1.51	16000	0.84
2000	6.84	10000	1.36	17000	0.80
3000	4.52	11000	1.23	18000	0.75
4000	3.40	12000	1.13	19000	0.71
5000	2.76	13000	1.04	20000	0.68
6000	2.26	14000	0.97		
7000	1.93	15000	0.90		
8000	1.69				

Capacitive reactance

The reactance of a capacitor, or its opposition to the flow of an alternating current, varies inversely with frequency and with capacitance. Capacitive reactance, always expressed in ohms, is based on the ability of a capacitor to store a charge or counter-electromotive force. This emf, acting in opposition to the applied voltage, reduces the amount of current flowing in a circuit, hence produces an effect analogous to that of a resistor. With a resistor, though, the current through it and the voltage across it are in phase. However, the counter emf of a capacitor, causes the voltage to lag behind the current. Ideally, the phase angle is 90°, but in practice the phase angle is less than this.

Table 16 on page 52 gives the reactance of capacitors ranging from .0001 μf to .0005 μf for frequencies ranging from 10 to 5,000 kc. Table 16 on page 53 is for capacitors having values from 0.25 to 3μf and for frequencies from 25 to 20,000 cycles. Both tables can be extended if you will keep in mind that doubling the frequency will halve the reactance. The same effect can be obtained by doubling the capacitance. Similarly, halving the frequency or capacitance will double the reactance. Naturally, you can apply other multiplication or division factors as well.

Examples:

What is the reactance of a .01-μf capacitor at a frequency of 1,000 cps? What will happen to this reactance if the frequency is increased to 10,000 cps?

Table 16 on page 53 shows a frequency of 1,000 cps, but does not have a capacitance value marked .01. Locate 1,000 in the left-hand column and move horizontally to the right until you reach the number 159 under the heading of *1.0* μf. We can change 1.0 μf to .01 by dividing it by 100. When we do this, we must multiply 159 by 100. Our answer is then 15900 ohms. If we increase the frequency to 10,000 cps we will be multiplying our original frequency by a factor of 10. This means that our reactance should be divided by a similar factor. Our answer will be 15900 divided by 10 or 1590 ohms.

What is the reactance of a .00015 μf capacitor at a frequency of 3,000 kc?

The Table shows that at this frequency the reactance is 354 ohms.

Table 16 — Capacitive Reactance (ohms)

Frequency (kc)	Capacitance (μf) .0001	.00015	.0002	.00025	.0003	.0005
10	159,235	106,157	79,618	63,694	53,078	31,847
20	79,618	53,079	39,809	31,848	26,539	15,924
30	53,078	35,836	26,539	21,232	17,693	10,616
40	39,809	26,540	19,905	15,924	13,270	7,962
50	31,847	21,230	15,924	12,740	10,616	6,370
60	26,539	17,693	13,270	10,616	8,847	5,308
70	22,748	15,165	11,374	9,098	7,852	4,549
80	19,905	13,270	9,953	7,962	6,635	3,981
90	17,693	11,795	8,847	7,078	5,897	3,539
100	15,924	10,615	7,962	6,370	5,308	3,185
150	10,616	7,077	5,308	4,246	3,539	2,123
200	7,962	5,308	3,981	3,186	2,654	1,593
250	6,369	4,246	3,185	2,548	2,123	1,274
300	5,308	3,538	2,654	2,124	1,770	1,062
350	4,549	3,033	2,275	1,820	1,516	910
400	3,981	2,654	1,991	1,594	1,326	797
450	3,538	2,539	1,769	1,414	1,179	707
500	3,185	2,123	1,592	1,274	1,062	637
550	2,895	1,930	1,448	1,158	965	579
600	2,654	1,769	1,327	1,062	885	531
650	2,449	1,633	1,225	980	816	490
700	2,275	1,516	1,138	910	758	455
750	2,123	1,416	1,062	850	708	425
800	1,991	1,327	896	798	663	399
850	1,873	1,249	937	750	624	375
900	1,769	1,179	885	708	589	354
950	1,676	1,117	838	670	559	335
1,000	1,592	1,062	796	637	530	319
2,000	796	531	398	319	265	159
2,500	637	425	319	255	212	127
3,000	531	354	266	212	177	106
3,500	455	303	228	182	152	91
4,000	398	265	199	159	133	80
4,500	354	254	177	141	118	71
5,000	319	212	159	127	106	64

Table 16 — Capacitive Reactance (ohms)

Frequency (cps)	Capacitance (μf) .25	.5	1.0	2.0	3.0
25	25,478	12,739	6,369	3,185	2,123
30	21,231	10,616	5,308	2,654	1,769
50	12,739	6,369	3,185	1,593	1,062
60	10,616	5,308	2,654	1,327	885
75	8,492	4,246	2,123	1,062	708
100	6,369	3,185	1,592	796	531
120	5,308	2,654	1,327	664	442
150	4,246	2,123	1,062	531	354
180	3,538	1,769	885	443	295
200	3,185	1,592	796	398	265
250	2,548	1,274	637	319	212
300	2,123	1,062	531	265	177
350	1,820	910	455	228	152
400	1,592	796	398	199	133
450	1,415	708	354	177	118
500	1,274	637	319	159	106
600	1,107	531	265	133	88
700	948	455	228	114	76
800	796	398	199	99	66
900	708	354	177	89	59
1,000	637	318	159	79	53
2,000	319	159	79	39	27
3,000	213	107	53	27	18
4,000	159	79	39	20	14
5,000	127	64	32	16	11
6,000	106	53	27	14	9
7,000	91	46	23	12	8
8,000	80	40	20	10	7
9,000	71	36	18	9	6
10,000	64	32	16	8	5
12,000	53	27	14	7	4.6
14,000	46	23	12	6	4
16,000	40	20	10	5	3.3
18,000	36	18	9	4.5	3
20,000	32	16	8	4	2.6

Capacitors in series

The total capacitance of series capacitors is always less than that of the smallest capacitor in the series network. As a general rule of thumb, if two capacitors are in series, and one has ten or more times the value of the other, the resultant total capacitance may be considered as slightly less than or equal to the value of the smaller capacitor.

Where two series capacitors have equal values, the resultant capacitance is one-half that of either unit. When three capacitors in series have equal values, the resultant capacitance is one-third that of any of the units.

Table 17 gives the resultant capacitance of two capacitors in series. The Table can be extended by moving the decimal point in the *C1* and *C2* columns an equal number of places to the right. The Table can also be used for finding the total capacitance of three series capacitors by doing a two-step operation, i.e.—determining the value of two capacitors and then combining the result with the remaining capacitor. C1 and C2 must be in similar units of μf or pf. The answers will then be in μf or pf.

Examples:

What is the capacitance of two series capacitors, having values of 47 pf and 15 pf?

Locate 47 pf in the *C2* column and move horizontally until you reach 11.37 in the *C1* column headed by the number 15. The answer is 11.37 pf. Note that you could also have solved this problem by locating 1.5 pf in the *C1* column, and then moving across to reach 4.7 pf (column *C2*). The answer would, of course, be 1.13 pf. Moving the decimal point one place to the right supplies an answer of 11.3.

You have a number of capacitors available, but you do not have one with a capacitance of 6 pf — the value you require. What capacitor combination can you use in series to give you 6 pf?

A value of exactly 6 pf is shown in the Table. It can be made by connecting a 10 pf and a 15 pf in series. Another combination which would result in a capacitance fairly close to 6 pf would be 33 pf and 7.5 pf, giving a total capacitance of 6.11 pf.

What is the total capacitance of a 68 μf capacitor and a 24 μf capacitor in series?

It isn't necessary to move the decimal point. Simply consider the Table as being completely in μf instead of pf. Locate 68 in the C2 column. Move across to intersect 24 μf in the C1 column. The answer is 17.74 μf.

Table 17 — Capacitors in Series

			C1		
C2	1	1.5	2	2.2	3
1	0.50	0.60	0.666	0.69	0.75
1.5	0.60	0.75	0.857	0.89	1.00
2	0.666	0.888	1.00	1.05	1.20
2.2	0.69	0.89	1.05	1.10	1.27
3	0.75	1.00	1.20	1.27	1.50
3.3	0.77	1.03	1.24	1.31	1.57
4	0.80	1.09	1.33	1.42	1.71
4.7	0.82	1.13	1.40	1.49	1.83
5	0.833	1.15	1.43	1.53	1.87
5.6	0.848	1.18	1.47	1.58	1.95
6.8	0.87	1.22	1.54	1.66	2.08
7.5	0.88	1.25	1.58	1.69	2.14
8.2	0.89	1.26	1.60	1.73	2.19
10	0.91	1.30	1.66	1.80	2.31
12	0.923	1.33	1.71	1.85	2.40
15	0.937	1.36	1.76	1.92	2.50
18	0.947	1.38	1.80	1.96	2.57
20	0.952	1.39	1.82	1.98	2.61
22	0.956	1.40	1.83	2.00	2.64
24	0.96	1.41	1.84	2.01	2.66
27	0.964	1.42	1.86	2.03	2.70
30	0.968	1.428	1.87	2.05	2.73
33	0.970	1.43	1.88	2.06	2.75
36	0.973	1.44	1.89	2.07	2.77
39	0.975	1.444	1.90	2.08	2.79
43	0.977	1.449	1.91	2.09	2.80
47	0.979	1.45	1.92	2.10	2.82
51	0.98	1.457	1.924	2.11	2.83
56	0.982	1.461	1.93	2.12	2.84
62	0.984	1.464	1.937	2.124	2.86
68	0.985	1.467	1.94	2.13	2.87
75	0.987	1.47	1.95	2.14	2.88
82	0.988	1.473	1.952	2.142	2.89
91	0.989	1.475	1.957	2.148	2.90
100	0.991	1.478	1.96	2.153	2.91

Table 17 — Capacitors in Series

C2	C1: 3.3	4	4.7	5	5.6
1	0.77	0.80	0.82	0.833	0.848
1.5	1.03	1.09	1.13	1.15	1.18
2	1.24	1.33	1.40	1.43	1.47
2.2	1.31	1.42	1.49	1.53	1.58
3	1.57	1.71	1.83	1.87	1.95
3.3	1.65	1.81	1.94	1.98	2.07
4	1.81	2.00	2.16	2.22	2.33
4.7	1.94	2.16	2.35	2.42	2.55
5	1.99	2.22	2.42	2.50	2.64
5.6	2.07	2.33	2.55	2.64	2.80
6.8	2.22	2.52	2.78	2.88	3.07
7.5	2.29	2.66	2.88	3.00	3.21
8.2	2.35	2.69	2.99	3.10	3.32
10	2.48	2.85	3.19	3.33	3.59
12	2.59	3.00	3.37	3.53	3.82
15	2.72	3.15	3.57	3.75	4.08
18	2.79	3.27	3.72	3.91	4.27
20	2.83	3.33	3.80	4.00	4.37
22	2.87	3.38	3.87	4.07	4.46
24	2.90	3.42	3.92	4.14	4.54
27	2.94	3.48	4.00	4.22	4.63
30	2.97	3.53	4.06	4.28	4.72
33	3.00	3.56	4.11	4.34	4.78
36	3.02	3.60	4.15	4.39	4.84
39	3.04	3.63	4.19	4.43	4.89
43	3.06	3.66	4.23	4.48	4.95
47	3.08	3.68	4.27	4.52	5.00
51	3.09	3.71	4.30	4.55	5.04
56	3.12	3.73	4.33	4.59	5.09
62	3.13	3.75	4.36	4.62	5.13
68	3.14	3.77	4.39	4.65	5.17
75	3.16	3.79	4.42	4.69	5.21
82	3.17	3.81	4.45	4.71	5.24
91	3.18	3.83	4.47	4.74	5.27
100	3.195	3.84	4.49	4.76	5.30

Table 17 — Capacitors in Series

	C1				
C2	6.8	7.5	8.2	10	12
1	0.87	0.88	0.89	0.91	0.92
1.5	1.22	1.25	1.26	1.30	1.33
2	1.54	1.58	1.60	1.66	1.71
2.2	1.66	1.69	1.73	1.80	1.86
3	2.08	2.14	2.19	2.31	2.40
3.3	2.22	2.29	2.35	2.48	2.59
4	2.52	2.66	2.69	2.85	3.00
4.7	2.78	2.88	2.99	3.19	3.37
5	2.88	3.00	3.10	3.33	3.53
5.6	3.07	3.21	3.32	3.59	3.82
6.8	3.40	3.56	3.66	4.05	4.34
7.5	3.56	3.75	3.92	4.29	4.61
8.2	3.66	3.92	4.10	4.51	4.87
10	4.05	4.29	4.51	5.00	5.45
12	4.34	4.61	4.87	5.45	6.00
15	4.68	5.00	5.30	6.00	6.66
18	4.93	5.29	5.63	6.43	7.20
20	5.07	5.45	5.81	6.66	7.50
22	5.19	5.59	5.97	6.87	7.77
24	5.29	5.71	6.11	7.06	8.00
27	5.43	5.87	6.29	7.29	8.31
30	5.54	6.00	6.44	7.50	8.57
33	5.64	6.11	6.57	7.67	8.80
36	5.72	6.20	6.67	7.82	9.00
39	5.79	6.29	6.77	7.95	9.18
43	5.87	6.38	6.88	8.11	9.40
47	5.94	6.47	6.98	8.24	9.56
51	6.00	6.53	7.06	8.36	9.71
56	6.06	6.61	7.15	8.48	9.88
62	6.14	6.69	7.24	8.61	10.05
68	6.18	6.75	7.32	8.72	10.20
75	6.23	6.82	7.39	8.82	10.34
82	6.28	6.87	7.45	8.91	10.46
91	6.32	6.93	7.52	9.01	10.60
100	6.37	6.96	7.58	9.09	10.71

Table 17 — Capacitors in Series

C2	C1: 15	18	20	22	24
3.3	2.72	2.79	2.83	2.87	2.90
4	3.15	3.27	3.33	3.38	3.42
4.7	3.57	3.72	3.80	3.87	3.92
5	3.75	3.91	4.00	4.07	4.14
5.6	4.08	4.27	4.37	4.46	4.54
6.8	4.68	4.93	5.07	5.19	5.29
7.5	5.00	5.29	5.45	5.59	5.71
8.2	5.30	5.63	5.81	5.97	6.11
10	6.00	6.43	6.66	6.87	7.06
12	6.66	7.20	7.50	7.77	8.00
15	7.50	8.18	8.57	8.92	9.23
18	8.18	9.00	9.47	9.90	10.29
20	8.57	9.47	10.00	10.43	10.91
22	8.92	9.90	10.48	11.00	11.48
24	9.23	10.29	10.91	11.48	12.00
27	9.64	10.80	11.49	12.12	12.71
30	10.00	11.25	12.00	12.69	13.33
33	10.31	11.65	12.45	13.20	13.89
36	10.59	12.00	12.86	13.66	14.40
39	10.83	12.32	13.22	14.07	14.86
43	11.21	12.69	13.65	14.55	15.40
47	11.37	13.02	14.03	14.93	15.89
51	11.59	13.30	14.37	15.37	16.32
56	11.83	13.62	14.74	15.79	16.80
62	12.08	13.95	15.12	16.24	17.30
68	12.29	14.23	15.45	16.62	17.74
75	12.50	14.52	15.79	17.01	18.18
82	12.68	14.76	16.08	17.35	18.57
91	12.88	15.03	16.40	17.71	18.99
100	13.04	15.25	16.67	18.03	19.35
150	13.64	16.07	17.65	19.19	20.69
180	13.85	16.36	18.00	19.60	21.18
200	13.95	16.51	18.18	19.82	21.43
220	14.04	16.63	18.33	20.00	21.64
250	14.15	16.79	18.52	20.22	21.90

Inductive reactance

The reactance of a coil or inductor varies directly with frequency and with inductance. Like capacitive reactance, coil reactance or inductive reactance is measured in ohms. Inductive reactance is an effect produced by the counter-electromotive force induced across the coil. This voltage, acting in opposition to the applied voltage, reduces the amount of circuit current.

As in the case of capacitors, the coil produces a phase shift. The current lags the voltage and in a hypothetical coil (one containing no resistance) would be 90°. In practice, the phase angle is less than this.

Table 18 on pages 60 and 61 supplies the inductive reactance of coils ranging from 10 to 100 millihenrys at frequencies ranging from 1 to 1,000 kc (1 megacycle). The Table, continued on pages 62, 63 and 64, supplies the reactance of coils from .001 henry to 10 henrys and covering a frequency of 25 to 1,000 cycles (1 kilocycle).

The behavior of an inductor is opposite that of a capacitor. Increasing the frequency or the inductance increases the reactance proportionately, and vice versa. Thus, doubling either the frequency or the inductance will double the reactance.

Examples:

What is the reactance of a coil having an inductance of .005 henry at a frequency of 1 kc?

Locate 1,000 cycles in the *frequency* column. Move to the right to the column headed by *.005*. The inductive reactance is given 31.40 ohms.

What is the reactance of a 5-henry choke coil at a frequency of 60 cps?

Locate 60 cycles in the *frequency* column and move to the right, finding an inductive reactance of 1,884 ohms in the column headed by the number 5. Note that the reactance of this coil at twice the frequency (120 cycles) is 3,768 ohms, double its original value.

What is the reactance of a 1-henry coil at a frequency of 150 cps?

A frequency of 150 cps is not listed in the Tables. Locate 50 cps, find the corresponding reactance of 314 ohms and multiply this value by 3 to get your answer. You could also get the same result by locating 75 cps in the Table, finding the reactance of 471 ohms and multiplying this result by 2. In either case the answer is 942 ohms.

Table 18 — Inductive Reactance (ohms)

Frequency (kc)	Inductance (millihenrys) 10	20	30	40	50
1	62.8	125.6	188.4	251.2	314
2	125.6	251.2	376.8	502.4	628
3	188.4	376.8	565.2	753.6	942
4	251.2	502.4	753.6	1004.8	1256
5	314	628	942	1256	1570
6	376.8	753.6	1130.4	1507.2	1884
7	439.6	879.2	1318.8	1758.4	2198
8	502.4	1004.8	1507.2	2009.6	2512
9	565.2	1130.4	1695.6	2260.8	2826
10	628	1256	1884	2512	3140
20	1256	2512	3768	5024	6280
25	1570	3140	4710	6280	7850
30	1884	3768	5652	7536	9420
40	2512	5024	7536	10048	12560
50	3140	6280	9420	12560	15700
60	3768	7536	11304	15072	18840
70	4396	8792	13188	17584	21980
80	5024	10048	15072	20096	25120
90	5652	11304	16956	22608	28260
100	6280	12560	18840	25120	31400
150	9420	18840	28260	37680	47100
200	12560	25120	37680	50240	62800
250	15700	31400	47100	62800	78500
300	18840	37680	56520	75360	94200
350	21980	43960	65940	87920	109900
400	25120	50240	75360	100480	125600
450	28260	56520	84780	113040	141300
500	31400	62800	94200	125600	157000
550	34540	69080	103620	138160	172700
600	37680	75360	113040	150720	188400
650	40820	81640	122460	163280	204100
700	43960	87920	131880	175840	219800
800	50240	100480	150720	200960	251200
900	56520	113040	168560	226080	282600
1000	62800	125600	188400	251200	314000

Table 18 — Inductive Reactance (ohms)

Frequency (kc)	Inductance (millihenrys) 60	70	80	90	100
1	376.8	439.6	502.4	565.2	628
2	753.6	879.2	1004.8	1130.4	1256
3	1130.4	1318.8	1507.2	1695.6	1884
4	1507.2	1758.4	2009.6	2260.8	2512
5	1884	2198	2512	2826	3140
6	2260.8	2637.6	3014.4	3391.2	3768
7	2637.6	3077.2	3516.8	3956.4	4396
8	3014.4	3516.8	4019.2	4521.6	5024
9	3391.2	3856.4	4521.6	5086.8	5652
10	3768	4396	5024	5652	6280
20	7536	8792	10048	11304	12560
25	9420	10990	12560	14130	15700
30	11304	13188	15072	16956	18840
40	15072	17584	20096	22608	25120
50	18840	21980	25120	28260	31400
60	22608	26376	30144	33912	37680
70	26376	30772	35168	39564	43960
80	30144	35168	40192	45216	50240
90	33912	38564	45216	50868	56520
100	37680	43960	50240	56520	62800
150	56520	65940	75360	84780	94200
200	75360	87920	100480	113040	125600
250	94200	109900	125600	141300	157000
300	113040	131880	150720	169560	188400
350	131880	153860	175840	197820	219800
400	150720	175840	200960	226080	251200
450	169560	192820	226080	254340	282600
500	188400	219800	251200	282600	314000
550	207240	241780	276320	310860	345400
600	226080	263760	301440	339120	376800
650	244920	285740	326560	367380	408200
700	263760	307720	351680	395640	439600
800	301440	351680	401920	452160	502400
900	339120	385640	452160	508680	565200
1000	376800	439600	502400	565200	628000

Table 18 — Inductive Reactance (ohms)

Frequency (cps)	Inductance (henrys) .001	.002	.003	.005	.01
25	.1570	.3140	.4710	.785	1.570
30	.1884	.3768	.5652	.942	1.884
40	.2512	.5024	.7536	1.256	2.512
45	.2826	.5652	.8478	1.413	2.826
50	.3140	.6280	.9420	1.570	3.140
55	.3454	.6908	1.0362	1.727	3.454
60	.3768	.7536	1.1304	1.884	3.768
65	.4082	.8164	1.2246	2.041	4.082
70	.4396	.8792	1.3188	2.198	4.396
75	.4710	.9420	1.4130	2.355	4.710
80	.5024	1.0048	1.5072	2.512	5.024
85	.5338	1.0676	1.6014	2.669	5.338
90	.5652	1.1304	1.6956	2.826	5.652
95	.5966	1.1932	1.7898	2.983	5.966
100	.6280	1.2560	1.8840	3.140	6.280
110	.6908	1.3816	2.0724	3.454	6.908
120	.7536	1.5072	2.2608	3.768	7.536
150	.942	1.8840	2.826	4.710	9.420
175	1.099	2.1980	3.297	5.495	10.990
200	1.256	2.5120	3.768	6.280	12.560
250	1.570	3.140	4.710	7.85	15.70
300	1.884	3.768	5.652	9.42	18.84
350	2.198	4.396	6.594	10.99	21.98
400	2.512	5.024	7.536	12.56	25.12
500	3.140	6.280	9.420	15.70	31.40
550	3.454	6.908	10.362	17.27	34.54
600	3.768	7.536	11.304	18.84	37.68
650	4.082	8.164	12.246	20.41	40.82
700	4.396	8.792	13.188	21.98	43.96
750	4.710	9.420	14.130	23.55	47.10
800	5.024	10.048	15.072	25.12	50.24
850	5.338	10.676	16.014	26.69	53.38
900	5.652	11.304	16.956	28.26	56.52
950	5.966	11.932	17.898	29.83	59.66
1000	6.280	12.560	18.840	31.40	62.80

Table 18 — Inductive Reactance (ohms)

Frequency (cps)	Inductance (henrys) 1	2	3	4	5
25	157.0	314.0	471.0	628.0	785
30	188.4	376.8	565.2	753.6	942
35	219.8	439.6	659.4	879.2	1099
40	251.2	502.4	753.6	1004.8	1256
45	282.6	565.2	847.8	1130.4	1413
50	314.0	628.0	942.0	1256.0	1570
55	345.4	690.8	1036.2	1318.6	1727
60	376.8	753.6	1130.4	1507.2	1884
65	408.2	816.4	1224.6	1632.8	2041
70	439.6	879.2	1318.8	1758.4	2198
75	471.0	942.0	1413.0	1884.0	2355
80	502.4	1004.8	1507.2	2009.6	2512
85	533.8	1067.6	1601.4	2135.2	2669
90	565.2	1130.4	1695.6	2260.8	2826
95	596.6	1193.2	1789.8	2386.4	2983
100	628.0	1256.0	1884.0	2512.0	3140
120	753.6	1507.2	2260.8	3014.4	3768
200	1256.0	2512.0	3768.0	5024.0	6280
240	1507.2	3014.4	4521.6	6028.8	7536
250	1570.0	3140.0	4710.0	6280.0	7850
300	1884	3768	5652	7536	9420
350	2198	4396	6594	8792	10990
360	2260	4522	6783	9044	11305
400	2512	5024	7536	10048	12560
450	2826	5652	8478	11304	14130
500	3140	6280	9420	12560	15700
550	3454	6908	10362	13816	17270
600	3768	7536	11304	15072	18840
650	4082	8164	12246	16328	20410
700	4396	8792	13188	17584	21980
750	4710	9420	14130	18840	23550
800	5024	10048	15072	20096	25120
850	5338	10676	16014	21352	26690
900	5652	11304	16956	22608	28260
1000	6280	12560	18840	25120	31400

Table 18 — Inductive Reactance (ohms)

Frequency (cps)	Inductance (henrys) 6	7	8	9	10
25	942.0	1099.0	1256.0	1413.0	1570
30	1130.4	1318.8	1507.2	1695.6	1884
35	1318.8	1538.6	1758.4	1978.2	2198
40	1507.2	1758.4	2009.6	2260.8	2512
45	1695.6	1978.2	2260.8	2543.4	2826
50	1884.0	2198.0	2512.0	2826.0	3140
55	2072.4	2417.8	2763.2	3108.6	3454
60	2260.8	2637.6	3014.4	3391.2	3768
65	2449.2	2857.4	3265.6	3673.8	4082
70	2637.6	3077.2	3516.8	3956.4	4396
75	2826.0	3297.0	3768.0	4239.0	4710
80	3014.4	3516.8	4019.2	4521.6	5024
85	3202.8	3736.6	4270.4	4804.2	5338
90	3391.2	3956.4	4521.6	5086.8	5652
95	3579.6	4176.2	4772.8	5396.4	5966
100	3768.0	4396.0	5024.0	5652.0	6280
120	4521.6	5275.2	6028.8	6782.4	7536
200	7536.0	8792.0	10048.0	11304	12560
240	9043.2	10550.4	12057.6	13565	15072
250	9420.0	10990.0	12460.0	14130	15700
300	11304	13188	15072	16956	18840
350	13188	15386	17584	19782	21980
360	13414	15826	18086	20347	22608
400	15072	17584	20096	22608	25120
450	16956	19782	22608	25434	28260
500	18840	21980	25120	28260	31400
550	20724	24178	27632	31086	34540
600	22608	26376	30124	33912	37680
650	24492	28574	32656	36738	40820
700	26376	30772	35168	39564	43960
750	28260	32970	37680	42390	47100
800	30144	35168	40192	45216	50240
850	32028	37366	42704	48042	53380
900	33912	39564	45216	50868	56520
1000	37680	43960	50240	56520	62800

L-C product for resonance

Table 19 shows the relationship between the wavelength in meters, the frequency in kilocycles and the inductance-capacitance product (L x C) required to produce resonance. The inductance is in microhenrys and the capacitance is in microfarads.

In an L-C circuit a condition of resonance is reached when the reactive elements are equal — that is, when the inductive and capacitive reactances are identical. When the inductance and the capacitance are both in microunits, that is, microhenrys and microfarads, the resonant frequency will be in kilocycles.

To find the resonant frequency without resorting to formulas, multiply the values of L and C, first converting these to microhenrys and microfarads. Knowing the L-C product, you can then find the resonant frequency by using Table 19. At the same time the Table also supplies the wavelength in meters.

Examples:

What is the wavelength in meters of a circuit when the inductance is 221 μh and the capacitance is 100 $\mu\mu$f.

The Table requires that the capacitance be in microfarads. 100 $\mu\mu$f is equivalent to .0001μf. Now multiply 221 by .0001. Your answer will be .0221. Locate this value in the *L x C* column in the Table. You will find that the frequency in kilocycles is 1,071 and the corresponding wavelength is 280 meters.

What is the resonant frequency of a circuit whose inductance has a value of 250 $\mu\mu$f and an inductance of 136 μh?

The inductance value can be used as it is, but the capacitance must be changed to microfarads. 250 $\mu\mu$f is equivalent to .00025 μf. The product of .00025 and 136 is .0340. The Table does not list such a value, but it does have a value that is close. The *L x C* column shows this to be 0.0345 with a corresponding frequency in kilocycles of 857. The wavelength is 350 meters.

You want a circuit that will be resonant at 5 megacycles. What must be the value of the L-C product?

5 megacycles is equal to 5,000 kilocycles. The Table shows that the L-C product is 0.0010140. Any combination of inductance and capacitance producing this product will be resonant at 5 megacycles.

Table 19 — L-C Product for Resonance

Wave-length (meters)	Frequency (kc)	L x C	Wave-length (meters	Frequency (kc)	L x C
1	300,000	0.0000003	270	1,111	0.0205
2	150,000	0.0000111	280	1,071	0.0221
3	100,000	0.0000018	290	1,034	0.0237
4	75,000	0.0000045	300	1,000	0.0253
5	60,000	0.0000057	310	968	0.0270
6	50,000	0.0000101	320	938	0.0288
7	42,900	0.0000138	330	909	0.0306
8	37,500	0.0000180	340	883	0.0325
9	33,333	0.0000228	350	857	0.0345
10	30,000	0.0000282	360	834	0.0365
20	15,000	0.0001129	370	811	0.0385
30	10,000	0.0002530	380	790	0.0406
40	7,500	0.0004500	390	769	0.0428
50	6,000	0.0007040	400	750	0.0450
60	5,000	0.0010140	410	732	0.0473
70	4,290	0.0013780	420	715	0.0496
80	3.750	0.0018010	430	698	0.0520
90	3,333	0.0022800	440	682	0.0545
100	3,000	0.00282	450	667	0.0570
110	2,727	0.00341	460	652	0.0596
120	2,500	0.00405	470	639	0.0622
130	2,308	0.00476	480	625	0.0649
140	2,143	0.00552	490	612	0.0676
150	2,000	0.00633	500	600	0.0704
160	1,875	0.00721	505	594	0.0718
170	1,764	0.00813	510	588	0.0732
180	1,667	0.00912	515	583	0.0747
190	1,579	0.01015	520	577	0.0761
200	1,500	0.01126	525	572	0.0776
210	1,429	0.01241	530	566	0.0791
220	1,364	0.01362	535	561	0.0806
230	1,304	0.01489	540	556	0.0821
240	1,250	0.01621	545	551	0.0836
250	1,200	0.01759	550	546	0.0852
260	1,154	0.01903	555	541	0.0867

Table 19 — L-C Product for Resonance

Wave-length (meters)	Frequency (kc)	L x C	Wave-length (meters	Frequency (kc)	L x C
560	536	0.0883	735	408	0.1521
565	531	0.0899	740	405	0.1541
570	527	0.0915	745	403	0.1562
575	522	0.0931	750	400	0.1583
580	517	0.0947	755	397	0.1604
585	513	0.0963	760	395	0.1626
590	509	0.0980	765	392	0.1647
595	504	0.0996	770	390	0.1669
600	500	0.1013	775	387	0.1690
605	496	0.1030	780	385	0.1712
610	492	0.1047	785	382	0.1734
615	488	0.1065	790	380	0.1756
620	484	0.1082	795	377	0.1779
625	480	0.1100	800	375	0.1801
630	476	0.1117	805	373	0.1824
635	472	0.1135	810	370	0.1847
640	469	0.1153	815	368	0.1870
645	465	0.1171	820	366	0.1893
650	462	0.1189	825	364	0.1916
655	458	0.1208	830	361	0.1939
660	455	0.1226	835	359	0.1962
665	451	0.1245	840	357	0.1986
670	448	0.1264	845	355	0.201
675	444	0.1283	850	353	0.203
680	441	0.1302	855	351	0.206
685	438	0.1321	860	349	0.208
690	435	0.1340	865	347	0.211
695	432	0.1360	870	345	0.213
700	429	0.1379	875	343	0.216
705	426	0.1399	880	341	0.218
710	423	0.1419	885	339	0.220
715	420	0.1439	890	337	0.223
720	417	0.1459	895	335	0.225
725	414	0.1479	900	333	0.228
730	411	0.1500	905	331	0.231

Table 19 — L-C Product for Resonance

Wave-length (meters)	Frequency (kc)	L x C	Wave-length (meters)	Frequency (kc)	L x C
910	330	0.233	955	314	0.257
915	328	0.236	960	313	0.259
920	326	0.238	965	311	0.262
925	324	0.241	970	309	0.265
930	323	0.243	975	308	0.268
935	321	0.246	980	306	0.270
940	319	0.249	985	305	0.273
945	317	0.251	990	303	0.276
950	316	0.254	995	302	0.279
			1000	300	0.282

Impedance

The impedance of a series R-C, R-L or R-L-C circuit is the vector sum of the individual reactances and resistance. Table 20 on pages 70 to 75 inclusive, supplies the impedance in ohms, when the values of R and X are known. X can represent either inductive or capacitive reactance, or X may be the vector sum of these reactive components when both are present in the circuit.

If you have both types of reactance, simply subtract one from the other to get the value of X. It makes no difference which reactive component (inductance or capacitance) has the larger reactance. Subtract the value of the smaller reactance from that of the larger to obtain the value of X.

Table 20 covers a range of X and of R from 1 ohm to 35 ohms. The Table can be extended by moving the decimal point an equal number of places for R, X and the answer. Thus, if you had a resistor with a value of 30 ohms and a reactance with a value of 90 ohms, you could consider 3 in the *R* column as 30, and 9 in the *X* column as 90. The value of impedance is given in the Table as 9.49 ohms, but moving the decimal point one place to the right gives us an impedance of 94.9 ohms.

Examples:

What is the impedance of a series circuit using a 10-ohm resistor and a coil whose inductive reactance is 15 ohms?

Locate 15 in the *X* column. Move horizontally until you reach the column headed by the number *10*. The value of impedance is shown as 18.02 ohms.

A circuit consists of a 5-ohm resistor, a coil having an inductive reactance of 35 ohms and a capacitor having a capacitive reactance of 21 ohms. What is the impedance of this circuit?

Subtract the value of the smaller reactance from that of the larger. 35 — 21 = 14 ohms. This is our net reactance and constitutes our value of X. Using this value, locate 14 in the *X* column. Move horizontally until you reach the *5* column (R). The impedance is shown as 14.86 ohms.

You require an impedance of 30 ohms for an R-L-C circuit. What values of R and X can you use to obtain this impedance?

The Table shows that you can get this impedance by using an 18-ohm resistor and a reactance having a value of 24 ohms. This reactance may be a coil having an inductive reactance of this value, or a capacitor, or both components whose net reactance is 24 ohms. Of course you could also use a 24-ohm resistor and a reactance of 18 ohms. There are many other combinations in the Table that are very close to this desired 30-ohm impedance.

Table 20 — Impedance (in ohms) for Series R and X

X	R 1	2	3	4	5	6
1	1.41	2.24	3.16	4.12	5.10	6.08
2	2.24	2.83	3.61	4.47	5.39	6.32
3	3.16	3.61	4.24	5.00	5.83	6.71
4	4.12	4.47	5.00	5.57	6.40	7.21
5	5.10	5.39	5.83	6.40	7.07	7.81
6	6.08	6.32	6.71	7.21	7.81	8.48
7	7.07	7.28	7.62	8.06	8.60	9.22
8	8.06	8.25	8.54	8.94	9.43	10.00
9	9.06	9.22	9.49	9.85	10.29	10.81
10	10.05	10.19	10.44	10.77	11.18	11.66
11	11.04	11.18	11.40	11.70	12.08	12.52
12	12.04	12.16	12.36	12.64	13.00	13.41
13	13.03	13.15	13.34	13.60	13.92	14.31
14	14.03	14.14	14.31	14.56	14.86	15.23
15	15.03	15.13	15.29	15.52	15.81	16.15
16	16.03	16.12	16.28	16.49	16.76	17.09
17	17.03	17.12	17.26	17.46	17.72	18.03
18	18.03	18.11	18.25	18.44	18.68	18.97
19	19.03	19.10	19.24	19.42	19.65	19.92
20	20.02	20.05	20.22	20.40	20.62	20.88
21	21.02	21.10	21.21	21.38	21.59	21.84
22	22.02	22.09	22.20	22.36	22.56	22.80
23	23.02	23.09	23.19	23.35	23.54	23.75
24	24.02	24.08	24.19	24.33	24.52	24.74
25	25.02	25.08	25.18	25.32	25.50	25.71
26	26.02	26.08	26.17	26.31	26.48	26.68
27	27.02	27.07	27.16	27.29	27.46	27.66
28	28.02	28.07	28.16	28.28	28.44	28.64
29	29.02	29.07	29.15	29.27	29.43	29.61
30	30.02	30.07	30.15	30.27	30.41	30.59
31	31.02	31.06	31.14	31.26	31.40	31.58
32	32.01	32.06	32.14	32.24	32.39	32.55
33	33.01	33.06	33.14	33.24	33.38	33.54
34	34.01	34.06	34.14	34.24	34.37	34.53
35	35.01	35.06	35.13	35.23	35.36	35.51

Table 20 — Impedance (in ohms) for Series R and X

	R					
X	*7*	*8*	*9*	*10*	*11*	*12*
1	7.07	8.06	9.06	10.05	11.04	12.04
2	7.28	8.25	9.22	10.19	11.18	12.16
3	7.62	8.54	9.49	10.44	11.40	12.36
4	8.06	8.94	9.85	10.77	11.70	12.64
5	8.60	9.43	10.29	11.18	12.08	13.00
6	9.22	10.00	10.81	11.66	12.52	13.41
7	9.89	10.63	11.40	12.20	13.03	13.89
8	10.63	11.31	12.04	12.80	13.60	14.42
9	11.40	12.04	12.72	13.45	14.21	15.00
10	12.20	12.80	13.45	14.14	14.86	15.62
11	13.03	13.60	14.21	14.86	15.55	16.27
12	13.89	14.42	15.00	15.62	16.27	16.97
13	14.76	15.26	15.81	16.40	17.02	17.69
14	15.65	16.12	16.64	17.20	17.80	18.43
15	16.55	17.00	17.49	18.02	18.60	19.20
16	17.46	17.89	18.36	18.87	19.42	20.00
17	18.38	18.79	19.24	19.72	20.25	20.81
18	19.31	19.70	20.12	20.59	21.10	21.63
19	20.25	20.62	21.02	21.47	21.95	22.47
20	21.19	21.54	21.93	22.36	22.83	23.32
21	22.14	22.47	22.85	23.26	23.71	24.19
22	23.09	23.41	23.77	24.17	24.60	25.06
23	24.04	24.35	24.70	25.08	25.50	25.94
24	25.00	25.30	25.63	26.00	26.40	26.83
25	25.96	26.25	26.57	26.93	27.31	27.73
26	26.93	27.20	27.51	27.86	28.23	28.64
27	27.89	28.16	28.46	28.79	29.15	29.55
28	28.86	29.12	29.41	29.73	30.08	30.46
29	29.83	30.08	30.36	30.68	31.02	31.38
30	30.81	31.05	31.32	31.62	31.96	32.31
31	31.78	31.93	32.25	32.56	32.90	33.24
32	32.75	32.98	33.24	33.52	33.85	34.18
33	33.74	33.96	34.21	34.49	34.79	35.12
34	34.72	34.93	35.17	35.44	35.74	36.06
35	35.70	35.90	36.14	36.40	36.69	37.00

Table 20 — Impedance (in ohms) for Series R and X

	R					
X	13	14	15	16	17	18
1	13.03	14.03	15.03	16.03	17.03	18.03
2	13.15	14.14	15.13	16.12	17.12	18.11
3	13.34	14.31	15.29	16.28	17.26	18.25
4	13.60	14.56	15.52	16.49	17.46	18.44
5	13.92	14.86	15.81	16.76	17.72	18.68
6	14.31	15.23	16.15	17.09	18.03	18.97
7	14.76	15.65	16.55	17.47	18.38	19.31
8	15.26	16.12	17.00	17.89	18.79	19.70
9	15.81	16.64	17.49	18.36	19.24	20.12
10	16.40	17.20	18.02	18.87	19.72	20.59
11	17.02	17.80	18.60	19.42	20.25	21.10
12	17.69	18.43	19.20	20.00	20.81	21.63
13	18.38	19.10	19.84	20.62	21.40	22.20
14	19.10	19.79	20.51	21.26	22.02	22.80
15	19.84	20.51	21.21	21.93	22.67	23.43
16	20.62	21.26	21.93	22.63	23.35	24.08
17	21.40	22.02	22.67	23.35	24.04	24.76
18	22.20	22.80	23.43	24.08	24.76	25.46
19	23.02	23.60	24.20	24.84	25.50	26.17
20	23.85	24.41	25.00	25.61	26.25	26.91
21	24.70	25.24	25.81	26.40	27.02	27.66
22	25.55	26.08	26.63	27.20	27.80	28.43
23	26.42	26.93	27.46	28.02	28.60	29.21
24	27.29	27.78	28.30	28.84	29.41	30.00
25	28.18	28.65	29.15	29.68	30.23	30.81
26	29.07	29.53	30.02	30.53	31.06	31.62
27	29.97	30.41	30.89	31.38	31.91	32.45
28	30.87	31.30	31.77	32.35	32.76	33.29
29	31.78	32.21	32.65	33.12	33.62	34.14
30	32.70	33.11	33.54	34.00	34.48	34.99
31	33.62	34.01	34.44	34.89	35.36	35.85
32	34.54	35.50	35.90	36.33	36.78	37.26
33	35.47	35.85	36.25	36.67	37.12	37.59
34	36.40	36.77	37.16	37.58	38.01	38.47
35	37.34	37.60	38.08	38.48	38.91	39.36

Table 20 — Impedance (in ohms) for Series R and X

	R					
X	19	20	21	22	23	24
1	19.03	20.02	21.02	22.02	23.02	24.02
2	19.10	20.10	21.10	22.09	23.09	24.08
3	19.24	20.22	21.21	22.20	23.19	24.19
4	19.42	20.40	21.38	22.36	23.35	24.33
5	19.65	20.62	21.59	22.56	23.54	24.52
6	19.92	20.88	21.84	22.80	23.77	24.74
7	20.25	21.18	22.14	23.09	24.04	25.00
8	20.62	21.54	22.47	23.41	24.35	25.30
9	21.02	21.93	22.85	23.77	24.70	25.63
10	21.47	22.36	23.26	24.17	25.08	26.00
11	21.95	22.82	23.71	24.60	25.50	26.40
12	22.47	23.32	24.19	25.06	25.94	26.83
13	23.02	23.85	24.70	25.55	26.42	27.29
14	23.60	24.41	25.24	26.08	26.93	27.78
15	24.20	25.00	25.81	26.63	27.46	28.30
16	24.84	25.61	26.40	27.20	28.02	28.84
17	25.50	26.25	27.02	27.80	28.60	29.41
18	26.17	26.91	27.66	28.43	29.21	30.00
19	26.86	27.59	28.32	29.07	29.83	30.61
20	27.59	28.28	29.00	29.73	30.48	31.24
21	28.32	29.00	29.70	30.41	31.14	31.89
22	29.07	29.73	30.41	31.11	31.83	32.56
23	29.83	30.48	31.14	31.83	32.52	33.24
24	30.61	31.24	31.89	32.56	33.24	33.94
25	31.40	32.02	32.65	33.30	33.97	34.66
26	32.20	32.80	33.42	34.06	34.71	35.38
27	33.02	33.60	34.21	34.83	35.47	36.13
28	33.85	34.41	35.01	35.61	36.24	36.88
29	34.67	35.23	35.81	36.40	37.01	37.64
30	35.51	36.06	36.62	37.20	37.80	38.42
31	36.36	36.89	37.44	38.01	38.60	39.21
32	37.22	37.73	38.28	38.83	39.41	40.00
33	38.08	38.59	39.12	39.66	40.22	40.81
34	38.95	39.45	39.96	40.40	41.05	41.62
35	39.82	40.31	40.82	41.34	41.88	42.44

Table 20 — Impedance (in ohms) for Series R and X

X	R 25	26	27	28	29	30
1	25.02	26.02	27.02	28.02	29.02	30.02
2	25.08	26.08	27.07	28.07	29.07	30.07
3	25.18	26.17	27.17	28.16	29.15	30.15
4	25.32	26.31	27.29	28.28	29.27	30.27
5	25.50	26.46	27.46	28.44	29.43	30.41
6	25.71	26.68	27.66	28.64	29.61	30.59
7	25.98	26.93	27.89	28.86	29.83	30.81
8	26.25	27.20	28.16	29.12	30.08	31.05
9	26.57	27.51	28.46	29.41	30.36	31.32
10	26.93	27.86	28.79	29.73	30.68	31.62
11	27.31	28.23	29.15	30.08	31.02	31.95
12	27.73	28.64	29.55	30.46	31.38	32.31
13	28.18	29.07	29.97	30.87	31.78	32.60
14	28.65	29.53	30.41	31.30	32.20	33.11
15	29.15	30.02	30.89	31.77	32.64	33.54
16	29.68	30.53	31.38	32.25	33.12	33.80
17	30.23	31.06	31.91	32.76	33.62	34.48
18	30.81	31.62	32.45	33.29	34.13	34.99
19	31.40	32.20	33.02	33.85	34.67	35.51
20	32.02	32.80	33.60	34.41	35.23	36.06
21	32.65	33.42	34.21	35.01	35.81	36.62
22	33.30	34.06	34.83	35.61	36.40	37.20
23	33.97	34.71	35.47	36.24	37.01	37.80
24	34.66	35.38	36.13	36.88	37.64	38.42
25	35.36	36.07	36.70	37.54	38.29	39.05
26	36.07	36.77	37.48	38.21	38.95	39.60
27	36.70	37.48	38.18	38.80	39.62	40.36
28	37.54	38.21	38.71	39.50	40.31	41.04
29	38.29	38.95	39.62	40.31	41.01	41.73
30	39.05	39.60	40.36	41.04	41.73	42.43
31	39.81	40.46	41.11	41.77	42.44	43.14
32	40.61	41.23	41.87	42.52	43.19	43.86
33	41.40	42.01	42.64	43.28	43.93	44.50
34	42.20	42.80	43.42	44.05	44.69	45.34
35	43.01	43.60	44.20	44.82	45.45	46.00

Table 20 — Impedance (in ohms) for Series R and X

X	R 31	R 32	R 33	R 34	R 35
1	31.01	32.02	33.02	34.02	35.01
2	31.06	32.06	33.06	34.06	35.06
3	31.14	32.14	33.14	34.13	35.13
4	31.26	32.25	33.24	34.23	35.23
5	31.40	32.39	33.38	34.37	35.36
6	31.57	32.56	33.54	34.53	35.51
7	31.78	32.76	33.74	34.71	35.69
8	32.02	32.99	33.96	34.93	35.90
9	32.28	33.24	34.21	35.17	36.14
10	32.57	33.53	34.48	35.36	36.40
11	32.89	33.85	34.79	35.74	36.69
12	33.24	34.18	35.11	36.06	36.80
13	33.62	34.53	35.48	36.40	37.34
14	34.02	34.93	35.85	36.77	37.60
15	34.44	35.34	36.25	37.16	38.08
16	34.89	35.78	36.67	37.58	38.48
17	35.37	36.24	37.12	38.01	38.90
18	35.85	36.72	37.59	38.47	39.36
19	36.36	37.22	38.08	38.95	39.82
20	36.89	37.74	38.59	39.46	40.31
21	37.44	38.28	39.12	39.96	40.82
22	38.01	38.83	39.66	40.40	41.34
23	38.60	39.41	40.22	41.05	41.88
24	39.21	40.00	40.80	41.63	42.44
25	39.81	40.61	41.40	42.20	43.01
26	40.46	41.23	42.01	42.80	43.60
27	41.11	41.87	42.64	43.42	44.20
28	41.77	42.52	43.28	44.05	44.82
29	42.44	43.19	43.93	44.69	45.45
30	43.14	43.86	44.50	45.34	46.00
31	43.84	44.55	45.28	46.01	46.76
32	44.55	45.26	45.97	46.69	47.42
33	45.28	45.98	46.68	47.38	48.10
34	46.01	46.69	47.38	48.08	48.70
35	46.75	47.42	48.10	48.70	49.40

Vector conversion

Table 21, beginning on page 77, can be used to change the form of vector quantities from j-notation to polar notation, or from polar to j-notation. The first column is the ratio of reactance, X, to resistance, R. The second column is the phase angle of the polar vector and is the angle whose tangent is X/R. The third column, Z, is the absolute magnitude of the vector in terms of X.

Examples:

The impedance of a circuit, expressed in polar form, is Z = 3000 — j4000. What is the absolute magnitude of the impedance and the phase angle?

3,000 represents the resistance R; 4,000 is the reactance X. The ratio X/R is 4,000/3,000 = 1.3333. The closest value of X/R in the Table is given on page 85 and is 1.3319. Immediately to the right is the phase angle of 53.1 degrees. However, since the reactance is negative and is given as —j4000, the phase angle is also negative and is −53.1 degrees. The value for Z in the column immediately to the right of the phase angle is 1.2505X. Since X is 4,000, Z = 1.250X = 5,000 ohms. Our answer, then, is that Z is 5,000 ohms and the phase angle is − 53.1 degrees.

Let's take the example just given and work it backwards. Suppose we have a circuit and we are told that the impedance is 5,000 ohms and the phase angle is − 53.1°. How could we express this in j-notation?

Start with the phase angle. In the third column on page 85 we see that 1.25X = Z. But we know that Z = 5,000 ohms. Since 1.25X = 5,000, then X = 4,000 ohms. Now move back to the first column. Here we see that X/R = 1.3319. Thus, 4,000/R = 1.3319. Solving for R we get R = 3,000 ohms. And, since we know that the phase angle is negative, we also know that our j-term will also be negative. Our answer, then, is 3,000 — j4000.

What is the impedance of a circuit whose resistance, R, is 1,000 ohms and whose reactance, X, is 775 ohms?

The ratio, X/R is 775/1,000 or 0.775. Locating the nearest equivalent number in the first column on page 83 of Table 21 gives us .77568. We see, immediately to the right of this number, that the phase angle is 37.8 degrees and, continuing to the right, that Z = 1.6316X. Thus, the impedance, Z = 1.6316 × 775 = 1,266 ohms.

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
0.00000	0.0	Z = R	0.06116	3.5	16.380 X
.00175	.1	572.96 X	.06291	3.6	15.926 X
.00349	.2	286.48 X	.06467	3.7	15.496 X
.00524	.3	190.98 X	.06642	3.8	15.089 X
.00698	.4	143.24 X	.06817	3.9	14.702 X
0.00873	0.5	114.59 X	0.06993	4.0	14.335 X
0.01047	0.6	95.495 X	0.07168	4.1	13.986 X
.01222	0.7	81.853 X	.07344	4.2	13.654 X
.01396	0.8	71.622 X	.07519	4.3	13.337 X
.01571	0.9	63.664 X	.07694	4.4	13.034 X
.01746	1.0	57.299 X	0.07870	4.5	12.745 X
0.01920	1.1	52.090 X			
0.02095	1.2	47.750 X	0.08046	4.6	12.469 X
.02269	1.3	44.077 X	.08221	4.7	12.204 X
.02444	1.4	40.930 X	.08397	4.8	11.950 X
.02618	1.5	38.201 X	.08573	4.9	11.707 X
.02793	1.6	35.814 X	.08749	5.0	11.474 X
0.02968	1.7	33.708 X	0.08925	5.1	11.249 X
0.03143	1.8	31.836 X	0.09101	5.2	11.033 X
.03317	1.9	30.161 X	.09277	5.3	10.826 X
.03492	2.0	28.654 X	.09453	5.4	10.626 X
.03667	2.1	27.290 X	.09629	5.5	10.433 X
0.03842	2.2	26.050 X	.09805	5.6	10.248 X
0.04016	2.3	24.918 X	0.09981	5.7	10.068 X
.04191	2.4	23.880 X	0.10158	5.8	9.8955 X
.04366	2.5	22.925 X	.10344	5.9	9.7283 X
.04541	2.6	22.044 X	.10510	6.0	9.5668 X
.04716	2.7	21.228 X	.10687	6.1	9.4105 X
0.04891	2.8	20.471 X	0.10863	6.2	9.2593 X
0.05066	2.9	19.766 X	0.11040	6.3	9.1129 X
.05241	3.0	19.107 X	.11217	6.4	8.9711 X
.05416	3.1	18.491 X	.11394	6.5	8.8337 X
.05591	3.2	17.914 X	.11570	6.6	8.7004 X
.05766	3.3	17.372 X	.11747	6.7	8.5711 X
0.05941	3.4	16.861 X	0.11924	6.8	8.4457 X

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
0.12107	6.9	8.3238 X	0.18173	10.3	5.5928 X
.12278	7.0	8.2055 X	.18353	10.4	5.5396 X
.12456	7.1	8.0905 X	.18534	10.5	5.4874 X
.12663	7.2	7.9787 X	.18714	10.6	5.4362 X
.12810	7.3	7.8700 X	0.18895	10.7	5.3860 X
0.12988	7.4	7.7642 X	0.19076	10.8	5.3367 X
0.13165	7.5	7.6613 X	.19257	10.9	5.2883 X
.13343	7.6	7.5611 X	.19438	11.0	5.2408 X
.13521	7.7	7.4634 X	.19619	11.1	5.1942 X
.13698	7.8	7.3683 X	.19800	11.2	5.1484 X
0.13876	7.9	7.2756 X	0.19982	11.3	5.1034 X
0.14054	8.0	7.1853 X	0.20163	11.4	5.0593 X
.14232	8.1	7.0972 X	.20345	11.5	5.0158 X
.14410	8.2	7.0112 X	.20527	11.6	5.9732 X
.14588	8.3	6.9273 X	.20709	11.7	5.9313 X
.14767	8.4	6.8454 X	0.20891	11.8	5.8901 X
0.14945	8.5	6.7755 X			
0.15124	8.6	6.6874 X	0.21073	11.9	5.8496 X
.15302	8.7	6.6111 X	.21256	12.0	4.8097 X
.15481	8.8	6.5365 X	.21438	12.1	4.7706 X
.15660	8.9	6.4637 X	.21621	12.2	4.7320 X
0.15838	9.0	6.3924 X	.21803	12.3	4.6942 X
0.16017	9.1	6.3228 X	0.21986	12.4	4.6569 X
.16196	9.2	6.2546 X	0.22169	12.5	4.6201 X
.16376	9.3	6.1880 X	.22353	12.6	4.5841 X
.16555	9.4	6.1227 X	.22536	12.7	4.5486 X
.16734	9.5	6.0588 X	.22719	12.8	4.5137 X
0.16914	9.6	5.9963 X	0.22903	12.9	4.4793 X
0.17093	9.7	5.9351 X	0.23087	13.0	4.4454 X
.17273	9.8	5.8751 X	.23270	13.1	4.4121 X
.17453	9.9	5.8163 X	.23455	13.2	4.3792 X
.17633	10.0	5.7588 X	.23693	13.3	4.3469 X
.17813	10.1	5.7023 X	0.23823	13.4	4.3150 X
0.17993	10.2	5.6470 X			

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
0.24008	13.5	4.2836 X	0.30001	16.7	3.4799 X
.24192	13.6	4.2527 X	.30192	16.8	3.4598 X
.24377	13.7	4.2223 X	.30382	16.9	3.4399 X
.24562	13.8	4.1923 X	.30573	17.0	3.4203 X
.24747	13.9	4.1627 X	.30764	17.1	3.4009 X
0.24933	14.0	4.1336 X	0.30995	17.2	3.3817 X
0.25118	14.1	4.1048 X	0.31146	17.3	3.3627 X
.25304	14.2	4.0765 X	.31338	17.4	3.3440 X
.25490	14.3	4.0486 X	.31530	17.5	3.3255 X
.25676	14.4	4.0211 X	.31722	17.6	3.3072 X
0.25862	14.5	3.9939 X	0.31914	17.7	3.2891 X
0.26048	14.6	3.9672 X	0.32106	17.8	3.2712 X
.26234	14.7	3.9408 X	.32299	17.9	3.2535 X
.26421	14.8	3.9147 X	.32492	18.0	3.2361 X
.26608	14.9	3.8890 X	.32685	18.1	3.2188 X
.26795	15.0	3.8637 X	0.32878	18.2	3.2017 X
0.26982	15.1	3.8387 X			
0.27169	15.2	3.8140 X	0.33072	18.3	3.1848 X
.27357	15.3	3.7897 X	.33265	18.4	3.1681 X
.27554	15.4	3.7657 X	.33459	18.5	3.1515 X
.27732	15.5	3.7420 X	.33654	18.6	3.1352 X
0.27920	15.6	3.7186 X	0.33848	18.7	3.1190 X
0.28109	15.7	3.6955 X	0.34043	18.8	3.1030 X
.28297	15.8	3.6727 X	.34238	18.9	3.0872 X
.28486	15.9	3.6502 X	.34433	19.0	3.0715 X
.28674	16.0	3.6279 X	.34628	19.1	3.0561 X
0.28863	16.1	3.6060 X	0.34824	19.2	3.0407 X
0.29053	16.2	3.5843 X	0.35019	19.3	3.0256 X
.29242	16.3	3.5629 X	.35215	19.4	3.0106 X
.29432	16.4	3.5418 X	.35412	19.5	2.9957 X
.29621	16.5	3.5209 X	.35608	19.6	2.9810 X
0.29811	16.6	3.5003 X	0.35805	19.7	2.9665 X

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
0.36002	19.8	2.9521 X	0.42036	22.8	2.5805 X
.36199	19.9	2.9379 X	.42242	22.9	2.5699 X
.36397	20.0	2.9238 X	.42447	23.0	2.5593 X
.36595	20.1	2.9098 X	.42654	23.1	2.5488 X
.36793	20.2	2.8960 X	0.42860	23.2	2.5384 X
0.36991	20.3	2.8824 X			
0.37190	20.4	2.8688 X	0.43067	23.3	2.5281 X
.37388	20.5	2.8554 X	.43274	23.4	2.5179 X
.37587	20.6	2.8422 X	.43481	23.5	2.5078 X
.37787	20.7	2.8290 X	.43689	23.6	2.4978 X
0.37986	20.8	2.8160 X	0.43897	23.7	2.4879 X
0.38186	20.9	2.8032 X	0.44105	23.8	2.4780 X
.38386	21.0	2.7904 X	.44314	23.9	2.4683 X
.38587	21.1	2.7778 X	.44523	24.0	2.4586 X
.38787	21.2	2.7653 X	.44732	24.1	2.4490 X
0.38988	21.3	2.7529 X	0.44942	24.2	2.4395 X
0.39189	21.4	2.7406 X	0.45152	24.3	2.4300 X
.39391	21.5	2.7285 X	.45362	24.4	2.4207 X
.39593	21.6	2.7165 X	.45573	24.5	2.4114 X
.39795	21.7	2.7045 X	.45783	24.6	2.4022 X
0.39997	21.8	2.6927 X	0.45995	24.7	2.3931 X
0.40200	21.9	2.6810 X	0.46206	24.8	2.3841 X
.40403	22.0	2.6695 X	.46418	24.9	2.3751 X
.40606	22.1	2.6580 X	.46631	25.0	2.3662 X
0.40809	22.2	2.6466 X	0.46843	25.1	2.3574 X
0.41013	22.3	2.6353 X	0.47056	25.2	2.3486 X
.41217	22.4	2.6242 X	.47270	25.3	2.3399 X
.41421	22.5	2.6131 X	.47483	25.4	2.3313 X
.41626	22.6	2.6022 X	.47697	25.5	2.3228 X
0.41831	22.7	2.5913 X	0.47912	25.6	2.3143 X

Table 21 — Vector Conversion

X/R	θ degrees	Z	X/R	θ degrees	Z
0.48127	25.7	2.3059 X	0.55203	28.9	2.0692 X
.48342	25.8	2.2976 X	.55431	29.0	2.0627 X
.48557	25.9	2.2894 X	.55659	29.1	2.0562 X
.48773	26.0	2.2812 X	0.55888	29.2	2.0498 X
0.48989	26.1	2.2730 X			
0.49206	26.2	2.2650 X	0.56117	29.3	2.0434 X
.49423	26.3	2.2570 X	.56347	29.4	2.0370 X
.49640	26.4	2.2490 X	.56577	29.5	2.0308 X
0.49858	26.5	2.2411 X	0.56808	29.6	2.0245 X
0.50076	26.6	2.2333 X	0.57039	29.7	2.0183 X
.50295	26.7	2.2256 X	.57270	29.8	2.0122 X
.50514	26.8	2.2179 X	.57502	29.9	2.0061 X
.50733	26.9	2.2103 X	.57735	30.0	2.0000 X
0.50952	27.0	2,2027 X	0.57968	30.1	1.9940 X
0.51172	27.1	2.1952 X	0.58201	30.2	1.9880 X
.51393	27.2	2.1877 X	.58435	30.3	1.9820 X
.51614	27.3	2.1803 X	.58670	30.4	1.9761 X
0.51835	27.4	2.1730 X	0.58904	30.5	1.9703 X
0.52057	27.5	2.1657 X	0.59140	30.6	1.9645 X
.52279	27.6	2.1584 X	.59376	30.7	1.9587 X
.52501	27.7	2.1513 X	.59612	30.8	1.9530 X
.52724	27.8	2.1441 X	0.59849	30.9	1.9473 X
0.52947	27.9	2.1371 X			
0.53171	28.0	2.1300 X	0.60086	31.0	1.9416 X
.53395	28.1	2.1231 X	.60324	31.1	1.9360 X
.53619	28.2	2.1162 X	.60562	31.2	1.9304 X
0.53844	28.3	2.1093 X	0.60801	31.3	1.9248 X
0.54070	28.4	2.1025 X	0.61040	31.4	1.9193 X
.54295	28.5	2.0957 X	.61280	31.5	1.9139 X
.54522	28.6	2.0890 X	.61520	31.6	1.9084 X
.54748	28.7	2.0824 X	0.61761	31.7	1.9030 X
0.54975	28.8	2.0757 X			

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
0.62003	31.8	1.8977 X	0.69243	34.7	1.7566 X
.62244	31.9	1.8924 X	.69502	34.8	1.7522 X
.62487	32.0	1.8871 X	0.69761	34.9	1.7478 X
.62730	32.1	1.8818 X			
0.62973	32.2	1.8766 X			
0.63217	32.3	1.8714 X	0.70021	35.0	1.7434 X
.63462	32.4	1.8663 X	.70281	35.1	1.7391 X
.63707	32.5	1.8611 X	.70542	35.2	1.7348 X
0.63953	32.6	1.8561 X	0.70804	35.3	1.7305 X
0.64199	32.7	1.8510 X	0.71066	35.4	1.7263 X
.64466	32.8	1.8460 X	.71329	35.5	1.7220 X
.64693	32.9	1.8410 X	.71593	35.6	1.7178 X
0.64941	33.0	1.8361 X	0.71857	35.7	1.7137 X
0.65189	33.1	1.8311 X	0.72122	35.8	1.7095 X
.65438	33.2	1.8263 X	.72388	35.9	1.7054 X
.65688	33.3	1.8214 X	.72654	36.0	1.7013 X
0.65938	33.4	1.8166 X	0.72921	36.1	1.6972 X
0.66188	33.5	1.8118 X	0.73189	36.2	1.6932 X
.66440	33.6	1.8070 X	.73457	36.3	1.6891 X
.66692	33.7	1.8023 X	.73726	36.4	1.6851 X
0.66944	33.8	1.7976 X	0.73996	36.5	1.6812 X
0.67197	33.9	1.7929 X	0.74266	36.6	1.6772 X
.67451	34.0	1.7883 X	.74538	36.7	1.6733 X
.67705	34.1	1.7837 X	0.74809	36.8	1.6694 X
0.67160	34.2	1.7791 X			
0.68215	34.3	1.7745 X	0.75082	36.9	1.6655 X
.68471	34.4	1.7700 X	.75355	37.0	1.6616 X
.68728	34.5	1.7655 X	.75629	37.1	1.6578 X
0.68985	34.6	1.7610 X	0.75904	37.2	1.6540 X

Table 21 — Vector Conversion

X/R	θ degrees	Z	X/R	θ degrees	Z
0.76179	37.3	1.6502 X	0.85107	40.4	1.5429 X
.76546	37.4	1.6464 X	.85408	40.5	1.5398 X
0.76733	37.5	1.6427 X	0.85710	40.6	1.5366 X
0.77010	37.6	1.6389 X	0.86013	40.7	1.5335 X
.77289	37.7	1.6352 X	.86318	40.8	1.5304 X
.77568	37.8	1.6316 X	.86623	40.9	1.5273 X
0.77848	37.9	1.6279 X	0.86929	41.0	1.5242 X
0.78128	38.0	1.6243 X	0.87235	41.1	1.5212 X
.78410	38.1	1.6206 X	.87543	41.2	1.5182 X
.78692	38.2	1.6170 X	0.87852	41.3	1.5151 X
0.78975	38.3	1.6135 X			
0.79259	38.4	1.6099 X	0.88162	41.4	1.5121 X
.79543	38.5	1.6064 X	.88472	41.5	1.5092 X
0.79829	38.6	1.6029 X	0.88784	41.6	1.5062 X
0.80115	38.7	1.5994 X	0.89097	41.7	1.5032 X
.80402	38.8	1.5959 X	.89410	41.8	1.5003 X
.80690	38.9	1.5924 X	0.89725	41.9	1.4974 X
0.80978	39.0	1.5890 X			
0.81268	39.1	1.5856 X	0.90040	42.0	1.4945 X
.81558	39.2	1.5822 X	.90357	42.1	1.4916 X
0.81849	39.3	1.5788 X	.90674	42.2	1.4887 X
			0.90993	42.3	1.4858 X
0.82141	39.4	1.5755 X	0.91312	42.4	1.4830 X
.82434	39.5	1.5721 X	.91633	42.5	1.4802 X
0.82727	39.6	1.5688 X	0.91955	42.6	1.4774 X
0.83022	39.7	1.5655 X	0.92277	42.7	1.4746 X
.83317	39.8	1.5622 X	.92601	42.8	1.4718 X
.83613	39.9	1.5590 X	0.92926	42.9	1.4690 X
0.83910	40.0	1.5557 X			
0.84208	40.1	1.5525 X	0.93251	43.0	1.4663 X
.84506	40.2	1.5493 X	.93578	43.1	1.4635 X
0.84806	40.3	1.5461 X	0.93906	43.2	1.4608 X

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
0.94235	43.3	1.4581 X	1.0538	46.5	1.3786 X
.94565	43.4	1.4554 X	1.0575	46.6	1.3763 X
0.94896	43.5	1.4527 X	1.0612	46.7	1.3740 X
0.95229	43.6	1.4501 X	1.0649	46.8	1.3718 X
.95562	43.7	1.4474 X	1.0686	46.9	1.3695 X
0.95896	43.8	1.4448 X	1.0724	47.0	1.3673 X
0.96232	43.9	1.4422 X	1.0761	47.1	1.3651 X
.96569	44.0	1.4395 X	1.0799	47.2	1.3629 X
0.96907	44.1	1.4370 X	1.0837	47.3	1.3607 X
0.97246	44.2	1.4344 X	1.0875	47.4	1.3585 X
.97586	44.3	1.4318 X	1.0913	47.5	1.3563 X
0.97927	44.4	1.4292 X	1.0951	47.6	1.3542 X
0.98270	44.5	1.4267 X	1.0990	47.7	1.3520 X
.98613	44.6	1.4242 X	1.1028	47.8	1.3499 X
0.98958	44.7	1.4217 X	1.1067	47.9	1.3477 X
0.99304	44.8	1.4192 X	1.1106	48.0	1.3456 X
0.99651	44.9	1.4167 X	1.1145	48.1	1.3435 X
1.0000	45.0	1.4142 X	1.1184	48.2	1.3414 X
1.0035	45.1	1.4117 X	1.1224	48.3	1.3393 X
1.0070	45.2	1.4093 X	1.1263	48.4	1.3372 X
1.0105	45.3	1.4069 X	1.1303	48.5	1.3352 X
1.0141	45.4	1.4040 X	1.1343	48.6	1.3331 X
1.0176	45.5	1.4020 X	1.1383	48.7	1.3311 X
1.0212	45.6	1.3996 X	1.1423	48.8	1.3290 X
1.0247	45.7	1.3972 X	1.1463	48.9	1.3270 X
1.0283	45.8	1.3949 X	1.1504	49.0	1.3250 X
1.0319	45.9	1.3925 X	1.1544	49.1	1.3230 X
1.0355	46.0	1.3902 X	1.1585	49.2	1.3210 X
1.0391	46.1	1.3878 X	1.1626	49.3	1.3190 X
1.0428	46.2	1.3855 X	1.1667	49.4	1.3170 X
1.0464	46.3	1.3832 X	1.1708	49.5	1.3151 X
1.0501	46.4	1.3809 X	1.1750	49.6	1.3131 X

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
1.1791	49.7	1.3112 X	1.3367	53.2	1.2488 X
1.1833	49.8	1.3092 X	1.3416	53.3	1.2472 X
1.1875	49.9	1.3073 X	1.3465	53.4	1.2456 X
1.1917	50.0	1.3054 X	1.3514	53.5	1.2440 X
1.1960	50.1	1.3035 X	1.3564	53.6	1.2424 X
1.2002	50.2	1.3016 X	1.3613	53.7	1.2408 X
1.2045	50.3	1.2997 X	1.3663	53.8	1.2392 X
1.2088	50.4	1.2978 X	1.3713	53.9	1.2376 X
1.2131	50.5	1.2960 X	1.3764	54.0	1.2361 X
1.2174	50.6	1.2941 X	1.3814	54.1	1.2345 X
1.2218	50.7	1.2922 X	1.3865	54.2	1.2329 X
1.2261	50.8	1.2904 X	1.3916	54.3	1.2314 X
1.2305	50.9	1.2886 X	1.3968	54.4	1.2298 X
1.2349	51.0	1.2867 X	1.4019	54.5	1.2283 X
1.2393	51.1	1.2849 X	1.4071	54.6	1.2268 X
1.2437	51.2	1.2831 X	1.4123	54.7	1.2253 X
1.2482	51.3	1.2813 X	1.4176	54.8	1.2238 X
1.2527	51.4	1.2795 X	1.4228	54.9	1.2223 X
1.2572	51.5	1.2778 X	1.4281	55.0	1.2208 X
1.2617	51.6	1.2760 X	1.4335	55.1	1.2193 X
1.2662	51.7	1.2742 X	1.4388	55.2	1.2178 X
1.2708	51.8	1.2725 X	1.4442	55.3	1.2163 X
1.2753	51.9	1.2707 X	1.4496	55.4	1.2149 X
1.2799	52.0	1.2690 X	1.4550	55.5	1.2134 X
1.2845	52.1	1.2673 X	1.4605	55.6	1.2119 X
1.2892	52.2	1.2656 X	1.4659	55.7	1.2105 X
1.2938	52.3	1.2639 X	1.4714	55.8	1.2091 X
1.2985	52.4	1.2622 X	1.4770	55.9	1.2076 X
1.3032	52.5	1.2605 X	1.4826	56.0	1.2062 X
1.3079	52.6	1.2588 X	1.4881	56.1	1.2048 X
1.3127	52.7	1.2571 X	1.4938	56.2	1.2034 X
1.3174	52.8	1.2554 X	1.4994	56.3	1.2020 X
1.3222	52.9	1.2538 X	1.5051	56.4	1.2006 X
1.3270	53.0	1.2521 X	1.5108	56.5	1.1992 X
1.3319	53.1	1.2505 X	1.5166	56.6	1.1978 X

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
1.5223	56.7	1.1964 X	1.7461	60.2	1.1524 X
1.5282	56.8	1.1951 X	1.7532	60.3	1.1512 X
1.5340	56.9	1.1937 X	1.7603	60.4	1.1501 X
1.5399	57.0	1.1924 X	1.7675	60.5	1.1489 X
1.5458	57.1	1.1910 X	1.7747	60.6	1.1478 X
1.5517	57.2	1.1897 X	1.7820	60.7	1.1467 X
1.5577	57.3	1.1883 X	1.7893	60.8	1.1456 X
1.5636	57.4	1.1870 X	1.7966	60.9	1.1445 X
1.5697	57.5	1.1857 X	1.8040	61.0	1.1433 X
1.5757	57.6	1.1844 X	1.8115	61.1	1.1422 X
1.5818	57.7	1.1831 X	1.8190	61.2	1.1411 X
1.5880	57.8	1.1818 X	1.8265	61.3	1.1401 X
1.5941	57.9	1.1805 X	1.8341	61.4	1.1390 X
1.6003	58.0	1.1792 X	1.8418	61.5	1.1379 X
1.6006	58.1	1.1779 X	1.8495	61.6	1.1368 X
1.6128	58.2	1.1766 X	1.8572	61.7	1.1357 X
1.6191	58.3	1.1753 X	1.8650	61.8	1.1347 X
1.6255	58.4	1.1741 X	1.8728	61.9	1.1336 X
1.6318	58.5	1.1728 X	1.8807	62.0	1.1326 X
1.6383	58.6	1.1716 X	1.8887	62.1	1.1315 X
1.6447	58.7	1.1703 X	1.8967	62.2	1.1305 X
1.6512	58.8	1.1691 X	1.9047	62.3	1.1294 X
1.6577	58.9	1.1678 X	1.9128	62.4	1.1284 X
1.6643	59.0	1.1666 X	1.9210	62.5	1.1274 X
1.6709	59.1	1.1654 X	1.9292	62.6	1.1264 X
1.6775	59.2	1.1642 X	1.9375	62.7	1.1253 X
1.6842	59.3	1.1630 X	1.9458	62.8	1.1243 X
1.6909	59.4	1.1618 X	1.9542	62.9	1.1233 X
1.6977	59.5	1.1606 X	1.9626	63.0	1.1223 X
1.7044	59.6	1.1594 X	1.9711	63.1	1.1213 X
1.7113	59.7	1.1582 X	1.9797	63.2	1.1203 X
1.7182	59.8	1.1570 X	1.9883	63.3	1.1193 X
1.7251	59.9	1.1559 X	1.9969	63.4	1.1184 X
1.7320	60.0	1.1547 X	2.0057	63.5	1.1174 X
1.7390	60.1	1.1535 X	2.0145	63.6	1.1164 X

Table 21 — Vector Conversion

X/R	θ degrees	Z	X/R	θ degrees	Z
2.0233	63.7	1.1155 X	2.3789	67.2	1.0847 X
2.0323	63.8	1.1145 X	2.3906	67.3	1.0840 X
2.0412	63.9	1.1135 X	2.4023	67.4	1.0832 X
2.0503	64.0	1.1126 X	2.4142	67.5	1.0824 X
2.0594	64.1	1.1116 X	2.4262	67.6	1.0816 X
2.0686	64.2	1.1107 X	2.4382	67.7	1.0808 X
2.0778	64.3	1.1098 X	2.4504	67.8	1.0801 X
2.0872	64.4	1.1088 X	2.4627	67.9	1.0793 X
2.0965	64.5	1.1079 X	2.4751	68.0	1.0785 X
2.1060	64.6	1.1070 X	2.4876	68.1	1.0778 X
2.1115	64.7	1.1061 X	2.5002	68.2	1.0770 X
2.1251	64.8	1.1052 X	2.5129	68.3	1.0763 X
2.1348	64.9	1.1043 X	2.5257	68.4	1.0755 X
2.1445	65.0	1.1034 X	2.5386	68.5	1.0748 X
2.1543	65.1	1.1025 X	2.5517	68.6	1.0740 X
2.1642	65.2	1.1016 X	2.5649	68.7	1.0733 X
2.1741	65.3	1.1007 X	2.5781	68.8	1.0726 X
2.1842	65.4	1.0998 X	2.5916	68.9	1.0719 X
2.1943	65.5	1.0989 X	2.6051	69.0	1.0711 X
2.2045	65.6	1.0981 X	2.6187	69.1	1.0704 X
2.2147	65.7	1.0972 X	2.6325	69.2	1.0697 X
2.2251	65.8	1.0963 X	2.6464	69.3	1.0690 X
2.2355	65.9	1.0955 X	2.6604	69.4	1.0683 X
2.2460	66.0	1.0946 X	2.6746	69.5	1.0676 X
2.2566	66.1	1.0938 X	2.6889	69.6	1.0669 X
2.2673	66.2	1.0929 X	2.7033	69.7	1.0662 X
2.2781	66.3	1.0921 X	2.7179	69.8	1.0655 X
2.2889	66.4	1.0913 X	2.7326	69.9	1.0648 X
2.2998	66.5	1.0904 X	2.7475	70.0	1.0642 X
2.3109	66.6	1.0896 X	2.7625	70.1	1.0635 X
2.3220	66.7	1.0888 X	2.7776	70.2	1.0628 X
2.3332	66.8	1.0880 X	2.7929	70.3	1.0622 X
2.3445	66.9	1.0872 X	2.8083	70.4	1.0615 X
2.3558	67.0	1.0864 X	2.8239	70.5	1.0608 X
2.3673	67.1	1.0855 X	2.8396	70.6	1.0602 X

Table 21 — Vector Conversion

X/R	θ degrees	Z	X/R	θ degrees	Z
2.8555	70.7	1.0595 X	3.5339	74.2	1.0393 X
2.8716	70.8	1.0589 X	3.5576	74.3	1.0387 X
2.8878	70.9	1.0582 X	3.5816	74.4	1.0382 X
2.9042	71.0	1.0576 X	3.6059	74.5	1.0377 X
2.9208	71.1	1.0570 X	3.6305	74.6	1.0372 X
2.9375	71.2	1.0563 X	3.6554	74.7	1.0367 X
2.9544	71.3	1.0557 X	3.6806	74.8	1.0362 X
2.9714	71.4	1.0551 X	3.7062	74.9	1.0358 X
2.9887	71.5	1.0545 X	3.7320	75.0	1.0353 X
3.0061	71.6	1.0539 X	3.7583	75.1	1.0348 X
3.0237	71.7	1.0533 X	3.7848	75.2	1.0343 X
3.0415	71.8	1.0527 X	3.8118	75.3	1.0338 X
3.0595	71.9	1.0521 X	3.8390	75.4	1.0334 X
3.0777	72.0	1.0515 X	3.8667	75.5	1.0329 X
3.0960	72.1	1.0509 X	3.8947	75.6	1.0324 X
3.1146	72.2	1.0503 X	3.9231	75.7	1.0320 X
3.1334	72.3	1.0497 X	3.9520	75.8	1.0315 X
3.1524	72.4	1.0491 X	3.9812	75.9	1.0311 X
3.1716	72.5	1.0485 X	4.0108	76.0	1.0306 X
3.1910	72.6	1.0479 X	4.0408	76.1	1.0302 X
3.2106	72.7	1.0474 X	4.0713	76.2	1.0297 X
3.2305	72.8	1.0468 X	4.1022	76.3	1.0293 X
3.2505	72.9	1.0462 X	4.1335	76.4	1.0288 X
3.2708	73.0	1.0457 X	4.1653	76.5	1.0284 X
3.2914	73.1	1.0451 X	4.1976	76.6	1.0280 X
3.3121	73.2	1.0466 X	4.2303	76.7	1.0276 X
3.3332	73.3	1.0440 X	4.2635	76.8	1.0271 X
3.3544	73.4	1.0435 X	4.2972	76.9	1.0267 X
3.3759	73.5	1.0429 X	4.3315	77.0	1.0263 X
3.3977	73.6	1.0424 X	4.3662	77.1	1.0259 X
3.4197	73.7	1.0419 X	4.4015	77.2	1.0225 X
3.4420	73.8	1.0413 X	4.4373	77.3	1.0251 X
3.4646	73.9	1.0408 X	4.4737	77.4	1.0247 X
3.4874	74.0	1.0403 X	4.5107	77.5	1.0243 X
3.5105	74.1	1.0398 X	4.5483	77.6	1.0239 X

Table 21 — Vector Conversion

X/R	θ degrees	Z	X/R	θ degrees	Z
4.5864	77.7	1.0235 X	6.4596	81.2	1.0119 X
4.6252	77.8	1.0231 X	6.5350	81.3	1.0116 X
4.6646	77.9	1.0227 X	6.6122	81.4	1.0114 X
4.7046	78.0	1.0223 X	6.6911	81.5	1.0111 X
4.7453	78.1	1.0220 X	6.7720	81.6	1.0108 X
4.7867	78.2	1.0216 X	6.8547	81.7	1.0106 X
4.8288	78.3	1.0212 X	6.9395	81.8	1.0103 X
4.8716	78.4	1.0208 X	7.0264	81.9	1.0101 X
4.9151	78.5	1.0205 X	7.1154	82.0	1.0098 X
4.9594	78.6	1.0201 X	7.2066	82.1	1.0096 X
5.0045	78.7	1.0198 X	7.3002	82.2	1.0093 X
5.0504	78.8	1.0194 X	7.3961	82.3	1.0091 X
5.0970	78.9	1.0191 X	7.4946	82.4	1.0089 X
5.1445	79.0	1.0187 X	7.5957	82.5	1.0086 X
5.1929	79.1	1.0184 X	7.6996	82.6	1.0084 X
5.2422	79.2	1.0180 X	7.8062	82.7	1.0082 X
5.2923	79.3	1.0177 X	7.9158	82.8	1.0079 X
5.3434	79.4	1.0174 X	8.0285	82.9	1.0077 X
5.3955	79.5	1.0170 X	8.1443	83.0	1.0075 X
5.4486	79.6	1.0167 X	8.2635	83.1	1.0073 X
5.5026	79.7	1.0164 X	8.3862	83.2	1.0071 X
5.5578	79.8	1.0160 X	8.5126	83.3	1.0069 X
5.6140	79.9	1.0157 X	8.6427	83.4	1.0067 X
5.6713	80.0	1.0154 X	8.7769	83.5	1.0065 X
5.7297	80.1	1.0151 X	8.9152	83.6	1.0063 X
5.7894	80.2	1.0148 X	9.0579	83.7	1.0061 X
5.8502	80.3	1.0145 X	9.2051	83.8	1.0059 X
5.9123	80.4	1.0142 X	9.3572	83.9	1.0057 X
5.9758	80.5	1.0139 X	9.5144	84.0	1.0055 X
6.0405	80.6	1.0136 X	9.6768	84.1	1.0053 X
6.1066	80.7	1.0133 X	9.8448	84.2	1.0051 X
6.1742	80.8	1.0130 X	10.019	84.3	1.0050 X
6.2432	80.9	1.0127 X	10.199	84.4	1.0048 X
6.3137	81.0	1.0125 X	10.385	84.5	1.0046 X
6.3859	81.1	1.0122 X	10.579	84.6	1.0044 X

Table 21 — Vector Conversion

$\frac{X}{R}$	θ degrees	Z	$\frac{X}{R}$	θ degrees	Z
10.780	84.7	1.0043 X	22.022	87.4	1.0010 X
10.988	84.8	1.0041 X	23.904	87.5	1.0009 X
11.205	84.9	1.0040 X	23.859	87.6	1.0009 X
11.430	85.0	1.0038 X	24.898	87.7	1.0008 X
11.664	85.1	1.0037 X	26.031	87.8	1.0007 X
11.909	85.2	1.0035 X	27.271	87.9	1.0007 X
12.163	85.3	1.0034 X	28.636	88.0	1.0006 X
12.429	85.4	1.0032 X	30.145	88.1	1.0005 X
12.706	85.5	1.0031 X	31.820	88.2	1.0005 X
12.996	85.6	1.0029 X	33.693	88.3	1.0004 X
13.229	85.7	1.0028 X	35.800	88.4	1.0004 X
13.617	85.8	1.0027 X	38.188	88.5	1.0003 X
13.951	85.9	1.0026 X	40.917	88.6	1.0003 X
14.301	86.0	1.0024 X	44.066	88.7	1.0002 X
14.668	86.1	1.0023 X	47.739	88.8	1.0002 X
15.056	86.2	1.0022 X	52.081	88.9	1.0002 X
15.464	86.3	1.0021 X	57.290	89.0	1.0001 X
15.894	86.4	1.0020 X	63.657	89.1	1.0001 X
16.350	86.5	1.0019 X	71.615	89.2	1.0001 X
16.832	86.6	1.0018 X	81.847	89.3	1.0001 X
17.343	86.7	1.0017 X	95.489	89.4	1.0000 X
17.886	86.8	1.0016 X	114.59	89.5	1.0000 X
18.464	86.9	1.0015 X	143.24	89.6	1.0000 X
19.081	87.0	1.0014 X	190.98	89.7	1.0000 X
19.740	87.1	1.0013 X	286.48	89.8	1.0000 X
20.446	87.2	1.0012 X	572.96	89.9	1.0000 X
21.205	87.3	1.0011 X	R = 0	90.0	1.0000 X

R-C time constants

R-C networks are used in a variety of applications, including differentiating and integrating networks, emphasis and de-emphasis circuits, as time delay elements in radio-control receivers, in oscillators, electronic switches, light flashers.

The time required to charge or discharge a capacitor depends on the amount of capacitance and the value of the associated resistor. The formula for the charge or discharge of a capacitor through a resistor is $T = R \times C$ in which the resistance is in ohms and the capacitance is in farads. The time, T, is the time in seconds for the capacitor to charge to 63% of its maximum, or for the charge on the capacitor to drop to 37% of its maximum.

Table 23 on pages 92 and 93 supplies the time constants for a capacitance range of 0.1 to 1 μf and from 0.1 to 10 seconds. Note that increasing the value of R or C will increase the time constant proportionately.

Although the formula for R-C time constants requires basic units, multiples can be used if conversions are made in accordance with Table 22 given below.

Table 22 — Multiples of Units for Time Constants

Where *R* is in	C is in	*L* is in	*T* is in
ohms	farads	henrys	seconds
ohms	μf	μh	μsec
kilohms	μf	henrys	msec
kilohms	—	mh	μsec
megohms	μf	—	seconds
megohms	μμf	henrys	μsec

Examples:

How long will it take to charge a capacitor having a value of 0.2 μf through a 500K resistor?

Locate 0.2 in the *capacitance* column in Table 23 on page 92. Immediately beneath this value you will see 500K. Move to the left and you will see that it will take 0.1 second.

What combination of resistance and capacitance can be used to obtain a 1-second time constant?

Locate 1 second in the *Time in Seconds* column. If you will now move to the right you will see that a number of possible combinations are available — 10 megohms and 0.1 μf; 5 megohms and 0.2 μf; 3.3 megohms and 0.3 μf, etc.

Table 23 — R-C Time Constants

Time (sec)	Capacitance (microfarads) 0.1	0.2	0.3	0.4	0.5
0.1	1.0M	500K	333K	250K	200K
0.15	1.5M	750K	500K	375K	300K
0.2	2.0M	1.00M	666K	500K	400K
0.25	2.5M	1.25M	833K	625K	500K
0.3	3.0M	1.50M	1.00M	750K	600K
0.35	3.5M	1.75M	1.17M	875K	700K
0.4	4.0M	2.00M	1.33M	1.00M	800K
0.45	4.5M	2.25M	1.50M	1.13M	900K
0.5	5.0M	2.50M	1.67M	1.25M	1.0M
0.55	5.5M	2.75M	1.83M	1.38M	1.1M
0.6	6.0M	3.00M	2.00M	1.50M	1.2M
0.65	6.5M	3.25M	2.17M	1.63M	1.3M
0.7	7.0M	3.50M	2.33M	1.75M	1.4M
0.75	7.5M	3.75M	2.50M	1.88M	1.5M
0.8	8.0M	4.00M	2.67M	2.00M	1.6M
0.85	8.5M	4.25M	2.83M	2.13M	1.7M
0.9	9.0M	4.50M	3.00M	2.25M	1.8M
0.95	9.5M	4.75M	3.17M	2.38M	1.9M
1.0	10.0M	5.00M	3.33M	2.50M	2.0M
1.5	15.0M	7.50M	5.00M	3.75M	3.0M
2.0	20.0M	10.00M	6.66M	5.00M	4.0M
2.5	25.0M	12.50M	8.33M	6.25M	5.0M
3.0	30.0M	15.00M	10.00M	7.50M	6.0M
3.5	35.0M	17.50M	11.66M	8.75M	7.0M
4.0	40.0M	20.00M	13.33M	10.00M	8.0M
4.5	45.0M	22.50M	15.00M	11.25M	9.0M
5.0	50.0M	25.00M	16.67M	12.50M	10.0M
5.5	55.0M	27.50M	18.33M	13.75M	11.0M
6.0	60.0M	30.00M	20.00M	15.00M	12.0M
6.5	65.0M	32.50M	21.67M	16.25M	13.0M
7.0	70.0M	35.00M	23.33M	17.50M	14.0M
7.5	75.0M	37.50M	25.00M	18.75M	15.0M
8.0	80.0M	40.00M	26.67M	20.00M	16.0M
9.0	90.0M	45.00M	30.00M	22.50M	18.0M
10.0	100.0M	50.00M	33.33M	25.00M	20.0M

K = kilohms   M = megohms

Table 23 — R-C Time Constants

Time (sec)	Capacitance (microfarads) 0.6	0.7	0.8	0.9	1.0
0.1	166K	143K	125K	111K	100K
0.15	250K	214K	188K	167K	150K
0.2	333K	286K	250K	222K	200K
0.25	417K	357K	313K	278K	250K
0.3	500K	429K	375K	333K	300K
0.35	583K	500K	438K	389K	350K
0.4	666K	571K	500K	444K	400K
0.45	750K	643K	563K	500K	450K
0.5	833K	714K	625K	555K	500K
0.55	917K	786K	688K	611K	550K
0.6	1.00M	857K	750K	666K	600K
0.65	1.08M	929K	813K	722K	650K
0.7	1.17M	1.00M	875K	778K	700K
0.75	1.25M	1.07M	938K	833K	750K
0.8	1.33M	1.14M	1.00M	889K	800K
0.85	1.42M	1.21M	1.06M	944K	850K
0.9	1.50M	1.29M	1.13M	1.00M	900K
0.95	1.58M	1.36M	1.19M	1.06M	950K
1.0	1.67M	1.43M	1.25M	1.11M	1.0M
1.5	2.50M	2.14M	1.88M	1.67M	1.5M
2.0	3.33M	2.86M	2.50M	2.22M	2.0M
2.5	4.17M	3.57M	3.13M	2.78M	2.5M
3.0	5.00M	4.29M	3.75M	3.33M	3.0M
3.5	5.83M	5.00M	4.38M	3.89M	3.5M
4.0	6.66M	5.71M	5.00M	4.44M	4.0M
4.5	7.50M	6.43M	5.63M	5.00M	4.5M
5.0	8.33M	7.14M	6.25M	5.55M	5.0M
5.5	9.17M	7.86M	6.88M	6.11M	5.5M
6.0	10.00M	8.57M	7.50M	6.66M	6.0M
6.5	10.83M	9.29M	8.13M	7.22M	6.5M
7.0	11.67M	10.00M	8.75M	7.78M	7.0M
7.5	12.50M	10.71M	9.38M	8.33M	7.5M
8.0	13.33M	11.43M	10.00M	8.89M	8.0M
9.0	15.00M	12.86M	11.25M	10.00M	9.0M
10.0	16.66M	14.28M	12.50M	11.11M	10.0M

K = kilohms M = megohms

R-L time constants

R-L circuits — circuits consisting of a resistor in series with an inductor — are used in timing circuits or in relays where the relay must make or break at predetermined times.

The time constant of an R-L circuit is based on the formula $T = L/R$, where T is the time in seconds, L the inductance in henrys and R is the resistance in ohms. The time in seconds is that required for the current to reach 63% of its maximum value, or to fall to 37% of its maximum. Time constants of L-R circuits are given in Table 24.

The resistance of the wire of which the coil is wound must be considered when calculating the time constant. This resistance is regarded as acting in series with the coil. Thus, if the resistance of a coil is 10 ohms and a 100-ohm series resistor is required for an R-L circuit, a value close to 90 ohms should be used. As a rule of thumb, if the resistance of the coil is 10% or more of the required resistance, it should be taken into consideration. In the case just mentioned, subtracting the 10 ohms of the coil from 100 ohms, shows that a 90-ohm resistor would be required. If the value of the external resistor is in the order of kilohms a coil whose resistance is just a few ohms could not seriously affect the time constant.

Examples:

A relay coil whose internal resistance is negligible, and whose inductance is .05 henry, will make (contacts will close) when the current through the coil reaches 63% of its peak. What value of series resistor is needed to have the relay close .008 second after the circuit is on?

Note that Table 24 does not include a time of .008 second nor an inductance of .05 henry. However, it is easy to extend the Table by moving the decimal point. Change .008 to 8 by moving its decimal point three places. The inductance, .05 henry, will then become 50. Locate the number 8 in the *time* column. Move across to the right until you reach the *50* column. The answer is 6.3 ohms. Note that the decimal point does not need to be moved in the answer. The reason for this is based on the time-constant formula. Rearranged, it is $R = L/T$. Equal increases, or decreases, in L and T have no effect on R.

A relay coil has an internal resistance of 30 ohms. The inductance of the coil is 10 henrys. What value of series resistor should be used with this relay for a time constant of 0.1 second?

Table 24 on page 95 shows that a time constant of 0.1 second for a 10-henry coil requires a series resistor of 100 ohms. However, the resistance of the coil is 30 ohms. Subtracting we get $100 - 30 = 70$. The series resistor should be 70 ohms.

Table 24 — R-L Time Constants

Time (sec)	Inductance (henrys) 10	20	30	40	50
0.1	100.0	200.0	300.0	400.0	500.0
0.15	66.7	133.3	200.0	266.7	333.3
0.2	50.0	100.0	150.0	200.0	250.0
0.25	40.0	80.0	120.0	160.0	200.0
0.3	33.3	66.7	100.0	133.3	166.7
0.35	28.6	57.1	86.6	114.3	142.9
0.4	25.0	50.0	75.0	100.0	125.0
0.45	22.2	44.4	66.7	88.9	111.1
0.5	20.0	40.0	60.0	80.0	100.0
0.55	18.2	36.4	54.5	72.7	90.9
0.6	16.7	33.3	50.0	66.7	83.3
0.65	15.4	30.8	46.2	61.5	76.9
0.7	14.3	28.6	42.9	57.1	71.4
0.75	13.3	26.7	40.0	53.3	66.7
0.8	12.5	25.0	37.5	50.0	62.5
0.85	11.8	23.5	35.3	47.1	58.8
0.9	11.1	22.2	33.3	44.4	55.5
0.95	10.5	21.1	31.6	42.1	52.6
1.0	10.0	20.0	30.0	40.0	50.0
1.5	6.7	13.3	20.0	26.7	33.3
2.0	5.0	10.0	15.0	20.0	25.0
2.5	4.0	8.0	12.0	16.0	20.0
3.0	3.3	6.7	10.0	13.3	16.7
3.5	2.9	5.7	8.7	11.4	14.3
4.0	2.5	5.0	7.5	10.0	12.5
4.5	2.2	4.4	6.7	8.9	11.1
5.0	2.0	4.0	6.0	8.0	10.0
5.5	1.8	3.6	5.5	7.3	9.1
6.0	1.7	3.3	5.0	6.7	8.3
6.5	1.5	3.1	4.6	6.2	7.7
7.0	1.4	2.9	4.3	5.7	7.1
7.5	1.3	2.7	4.0	5.3	6.7
8.0	1.2	2.5	3.8	5.0	6.3
9.0	1.1	2.2	3.3	4.4	5.5
10.0	1.0	2.0	3.0	4.0	5.0

All resistance values in ohms

Table 24 — R-L Time Constants

Time (sec)	Inductance (henrys) 60	70	80	90	100
0.1	600.0	700.0	800.0	900.0	1000.0
0.15	400.0	466.7	533.3	600.0	666.7
0.2	300.0	350.0	400.0	450.0	500.0
0.25	240.0	280.0	320.0	360.0	400.0
0.3	200.0	233.3	266.6	300.0	333.3
0.35	171.4	200.0	228.6	257.1	285.7
0.4	150.0	175.0	200.0	225.0	250.0
0.45	133.3	155.6	177.8	200.0	222.2
0.5	120.0	140.0	160.0	180.0	200.0
0.55	109.1	127.3	145.5	163.6	181.8
0.6	100.0	116.7	133.3	150.0	166.7
0.65	92.3	107.7	123.1	138.5	153.8
0.7	85.7	100.0	114.3	128.7	142.9
0.75	80.0	93.3	106.7	120.0	133.3
0.8	75.0	87.5	100.0	112.5	125.0
0.85	70.6	82.3	94.1	105.9	117.6
0.9	66.6	77.8	88.9	100.0	111.1
0.95	63.2	73.7	84.2	94.7	105.3
1.0	60.0	70.0	80.0	90.0	100.0
1.5	40.0	46.7	53.3	60.0	66.7
2.0	30.0	35.0	40.0	45.0	50.0
2.5	24.0	28.0	32.0	36.0	40.0
3.0	20.0	23.3	26.7	30.0	33.3
3.5	17.1	20.0	22.9	25.7	28.6
4.0	15.0	17.5	20.0	22.5	25.0
4.5	13.3	15.6	17.8	20.0	22.2
5.0	12.0	14.0	16.0	18.0	20.0
5.5	10.9	12.7	14.6	16.4	18.2
6.0	10.0	11.7	13.3	15.0	16.7
6.5	9.2	10.8	12.3	13.9	15.4
7.0	8.6	10.0	11.4	12.9	14.3
7.5	8.0	9.3	10.7	12.0	13.3
8.0	7.5	8.8	10.0	11.3	12.5
9.0	6.7	7.8	8.9	10.0	11.1
10.0	6.0	7.0	8.0	9.0	10.0

All resistance values in ohms

Angular velocity

In an ac generator, the rotating armature produces a voltage sine wave. We can represent the armature by a rotating vector r. The angle through which this vector sweeps is usually indicated by the Greek letter θ. The instantaneous values of the voltage produced are maximum when the phase angle, θ, is 90° and zero when that phase angle is 0° or 180°.

The radius vector r rotates about the origin, o, and is taken to rotate in a counterclockwise direction. The angular velocity of this rotating vector is the rate at which the angle, θ, is produced by its rotation. Angular velocity is conveniently represented by ω or $2\pi f$, in which 2π is a constant and is equal to 6.28. The frequency f, is in cycles per second.

Angular velocity, appears in formulas involving instantaneous values of sine waves of voltage or current ($e = E \max \sin \omega t$) and in formulas involving inductive reactance ($X_L = 2\pi fL$) and capacitive reactance ($X_C = 1/2 \pi fC$).

The solution of problems involving angular velocity is simplified by Table 25 on page 98. Here we have angular velocity corresponding to particular values of frequency.

Table 25 can be used for values of frequency other than those indicated simply by moving the decimal point. Thus, to find ω at a frequency of 4 kilocycles, find 40 in the f column. To change 40 cycles to 4 kilocycles we must multiply 40 by 100. This means that we must multiply the value of 251.20 (which is the value of ω for 40) by 100. The answer is 25,120. To get megacycle values, multiply both f and ω by 1,000,000.

Example:

What is the angular velocity of a generator, whose armature rotates at 1,800 revolutions per minute?

Divide 1,800 revolutions by 60 (60 seconds = 1 minute) to obtain the number of revolutions per second. 1,800/60 = 30 revolutions per second. In 30 revolutions the armature generates 30 complete sinewave cycles. The frequency, then, is 30. Locate 30 in the *frequency (f)* column of Table 25. The corresponding angular velocity is found to the right in the ω column. The answer is 188.4 radians per second.

Table 25 — Angular Velocity

f (cps)	ω	f (cps)	ω	f (cps)	ω
10	62.8	40	251.20	70	439.60
11	69.08	41	257.48	71	445.88
12	75.36	42	263.76	72	452.16
13	81.64	43	270.04	73	458.44
14	87.92	44	276.32	74	464.72
15	94.20	45	282.60	75	471.00
16	100.48	46	288.88	76	477.28
17	106.76	47	295.16	77	483.56
18	113.04	48	301.44	78	489.84
19	119.32	49	307.72	79	496.12
20	125.60	50	314.00	80	502.40
21	131.88	51	320.28	81	508.68
22	138.16	52	326.56	82	514.96
23	144.44	53	332.84	83	521.24
24	150.72	54	339.12	84	527.52
25	157.00	55	345.40	85	533.80
26	163.28	56	351.68	86	540.08
27	169.56	57	357.96	87	546.36
28	175.84	58	364.24	88	552.64
29	182.12	59	370.52	89	558.92
30	188.40	60	376.80	90	565.20
31	194.68	61	383.08	91	571.48
32	200.96	62	389.36	92	577.76
33	207.24	63	395.64	93	584.04
34	213.52	64	401.92	94	590.32
35	219.80	65	408.20	95	596.60
36	226.08	66	414.48	96	602.88
37	232.36	67	420.76	97	609.16
38	238.64	68	427.04	98	615.44
39	244.92	69	433.32	99	621.72
				100	628.00

Impedance and turns ratios

Transformers are conveniently regarded and used as impedance transformation devices. The impedance of a transformer varies as the square of the turns ratio. These ratios, in steps of 1 to 100, are given in Table 26, below. Consider the first number in the ratio as the transformer primary and the second number in the ratio as the transformer secondary.

Examples:

A step-down transformer has a turns ratio of 37 to 1. What is the impedance ratio?

Locate the turns ratio, 37:1, and immediately alongside you will find the impedance ratio of 1,369:1.

What is the impedance transformation of a step-up transformer having a turns ratio of 1:53?

Table 26 shows that the impedance transformation for this turns ratio is 1:2,809.

Table 26 — Impedance Ratio and Turns Ratio of a Transformer

Turns Ratio	*Impedance Ratio*	*Turns Ratio*	*Impedance Ratio*
100:1	10,000:1	85:1	7,225:1
99:1	9,801:1	84:1	7,056:1
98:1	9,604:1	83:1	6,889:1
97:1	9,409:1	82:1	6,724:1
96:1	9,216:1	81:1	6,571:1
95:1	9,025:1	80:1	6,400:1
94:1	8,836:1	79:1	6,241:1
93:1	8,649:1	78:1	6,084:1
92:1	8,464:1	77:1	5,929:1
91:1	8,281:1	76:1	5,776:1
90:1	8,100:1	75:1	5,625:1
89:1	7,921:1	74:1	5,476:1
88:1	7,744:1	73:1	5,329:1
87:1	7,569:1	72:1	5,184:1
86:1	7,396:1	71:1	5,041:1

Table 26 — Impedance Ratio and Turns Ratio of a Transformer

Turns Ratio	*Impedance Ratio*	*Turns Ratio*	*Impedance Ratio*
70:1	4,900:1	35:1	1,225:1
69:1	4,761:1	34:1	1,156:1
68:1	4,624:1	33:1	1,089:1
67:1	4,489:1	32:1	1,024:1
66:1	4,356:1	31:1	961:1
65:1	4,225:1	30:1	900:1
64:1	4,096:1	29:1	841:1
63:1	3,969:1	28:1	784:1
62:1	3,844:1	27:1	729:1
61:1	3,721:1	26:1	676:1
60:1	3,600:1	25:1	625:1
59:1	3,481:1	24:1	576:1
58:1	3,364:1	23:1	529:1
57:1	3,249:1	22:1	484:1
56:1	3,136:1	21:1	441:1
55:1	3,025:1	20:1	400:1
54:1	2,916:1	19:1	361:1
53:1	2,809:1	18:1	324:1
52:1	2,704:1	17:1	289:1
51:1	2,601:1	16:1	256:1
50:1	2,500:1	15:1	225:1
49:1	2,401:1	14:1	196:1
48:1	2,304:1	13:1	169:1
47:1	2,209:1	12:1	144:1
46:1	2,116:1	11:1	121:1
45:1	2,025:1	10:1	100:1
44:1	1,936:1	9:1	81:1
43:1	1,849:1	8:1	64:1
42:1	1,764:1	7:1	49:1
41:1	1,681:1	6:1	36:1
40:1	1,600:1	5:1	25:1
39:1	1,521:1	4.1	16:1
38:1	1,444:1	3:1	9:1
37:1	1,369:1	2:1	4:1
36:1	1,296:1	1:1	1:1

Table 26 — Impedance Ratio and Turns Ratio of a Transformer

Turns Ratio	*Impedance Ratio*	*Turns Ratio*	*Impedance Ratio*
1:100	1:10,000	1:69	1:4,761
1:99	1:9,801	1:68	1:4,624
1:98	1:9,604	1:67	1:4,489
1:97	1:9,409	1:66	1:4,356
1:96	1:9,216	1:65	1:4,225
1:95	1:9,025	1:64	1:4,096
1:94	1:8,836	1:63	1:3,969
1:93	1:8,649	1:62	1:3,844
1:92	1:8,464	1:61	1:3,721
1:91	1:8,281	1:60	1:3,600
1:90	1:8,100	1:59	1:3,481
1:89	1:7,921	1:58	1:3,364
1:88	1:7,744	1:57	1:3,249
1:87	1:7,569	1:56	1:3,136
1:86	1:7,396	1:55	1:3,025
1:85	1:7,225	1:54	1:2,916
1:84	1:7,056	1:53	1:2,809
1:83	1:6,889	1:52	1:2,704
1:82	1:6,724	1:51	1:2,601
1:81	1:6,571	1:50	1:2,500
1:80	1:6,400	1:49	1:2,401
1:79	1:6,241	1:48	1:2,304
1:78	1:6,084	1:47	1:2,209
1:77	1:5,929	1:46	1:2,116
1:76	1:5,776	1:45	1:2,025
1:75	1:5,625	1:44	1:1,936
1:74	1:5,476	1:43	1:1,849
1:73	1:5,329	1:42	1:1,764
1:72	1:5,184	1:41	1:1,681
1:71	1:5,041	1:40	1:1,600
1:70	1:4,900	1:39	1:1,521

Table 26 — Impedance Ratio and Turns Ratio of a Transformer

Turns Ratio	Impedance Ratio	Turns Ratio	Impedance Ratio
1:38	1:1,444	1:19	1:361
1:37	1:1,369	1:18	1:324
1:36	1:1,296	1:17	1:289
1:35	1:1,225	1:16	1:256
1:34	1:1,156	1:15	1:225
1:33	1:1,089	1:14	1:196
1:32	1:1,024	1:13	1:169
1:31	1: 961	1:12	1:144
1:30	1: 900	1:11	1:121
1:29	1: 841	1:10	1:100
1:28	1: 784	1:9	1: 81
1:27	1: 729	1:8	1: 64
1:26	1: 676	1:7	1: 49
1:25	1: 625	1:6	1: 36
1:24	1: 576	1:5	1: 25
1:23	1: 529	1:4	1: 16
1:22	1: 484	1:3	1: 9
1:21	1: 441	1:2	1: 4
1:20	1: 400	1:1	1: 1

The turns ratio of a transformer is specifically that — a ratio — and gives no indication of the actual number of turns used by the transformer. A transformer having 50 primary turns and 50 secondary turns has a 1:1 ratio. So does a transformer having 5,000 primary and 5,000 secondary turns.

To get the ratio, divide the larger number of turns by the smaller. Table 26 will then supply the impedance ratio.

Example:

A stepdown transformer has 2,465 primary turns and 85 secondary turns. What is the impedance ratio?

Divide 2,465 by 85. This supplies us with a ratio of 29:1. The Table shows the impedance ratio is 841:1. If the transformer had 85 primary turns and 2,465 secondary turns, the impedance ratio would be 1:841.

Watts-Horsepower

Motors are generally rated in terms of horsepower. But since a motor is an electro-mechanical device, we may be interested in knowing its rating in watts. The relationship between horsepower [HP] and power in watts is:

$$1 \text{ HP} = 745.7 \text{ watts}$$

Table 27 on page 104 gives the conversion between these two quantities. The Table can be easily extended by moving the decimal point in the same direction, for the same number of places, in both columns.

Examples:

A small motor is rated at one-tenth horsepower. What is its rating in watts?

The closest value to one-tenth horsepower in the Table is .100575 shown in the right-hand column under the heading *HP*. The power corresponding to this value is 75 watts.

A motor-generator is rated at one-half kilowatt. What is its equivalent horsepower rating?

One-half kilowatt is 500 watts. The Table does not list such a value but we can use the number 50 in place of 500. Locate the number 50 in the left-hand column headed by *watts*. Move the decimal point one place to the right and 50 becomes 500. The corresponding value of horsepower shown by Table 27 is .067050 HP. Moving the decimal point of this number by one decimal place [to the right] gives us our answer of 0.675050 HP. In practice we would probably round this to 0.7 HP.

What is the horsepower rating of a 1-kilowatt generator?

1 kilowatt is equal to 1,000 watts. We can use Table 27 by selecting the number 100 and moving its decimal point one place to the right, thus changing 100 to 1,000. The corresponding value of horsepower is .134100, but we must remember to move the decimal point here as well. Our answer is 1.341 HP.

A fractional HP motor is rated at .07 HP. What is its power rating in watts?

There is no value in the Table that corresponds exactly to .07. We do have two values, though, which are very close. One of these is .069732 and the other is .071073. Thus, this motor has a rating between 52 and 53 watts.

Table 27 — Watts and Horsepower

Watts	*HP*	*Watts*	*HP*	*Watts*	*HP*
1	.001341	34	.045594	67	.089847
2	.002682	35	.046935	68	.091188
3	.004023	36	.048278	69	.092529
4	.005364	37	.049617	70	.093870
5	.006705	38	.050958	71	.095211
6	.008046	39	.052299	72	.096552
7	.009387	40	.053640	73	.097893
8	.010728	41	.054981	74	.099234
9	.012069	42	.056322	75	.100575
10	.013410	43	.057663	76	.101916
11	.014751	44	.059004	77	.103257
12	.016092	45	.060345	78	.104598
13	.017433	46	.061686	79	.105939
14	.018774	47	.063027	80	.107280
15	.020115	48	.064368	81	.108261
16	.021456	49	.065709	82	.109962
17	.022797	50	.067050	83	.111303
18	.024138	51	.068391	84	.112644
19	.025479	52	.069732	85	.113985
20	.026820	53	.071073	86	.115326
21	.028161	54	.072414	87	.116667
22	.029502	55	.073755	88	.118008
23	.030843	56	.075096	89	.119349
24	.032184	57	.076437	90	.120690
25	.033525	58	.077778	91	.122031
26	.034866	59	.079119	92	.123372
27	.036207	60	.080460	93	.124713
28	.037548	61	.081801	94	.126054
29	.038889	62	.083142	95	.127395
30	.040230	63	.084483	96	.128736
31	.041571	64	.085824	97	.130077
32	.042912	65	.087165	98	.131418
33	.044253	66	.088506	99	.132759
				100	.134100

Transistor transformers

Table 28, below, lists representative characteristics of input, interstage and output transformers used in transistor radios. These characteristics include the turns ratio, the impedance of the primary and secondary windings, and their resistance.

Table 28 — Typical Characteristics of Input, Interstage and Output Transformers for Transistor Receivers

Application	*Turns Ratio Pri. to Sec.*	*Impedance in Ohms Pri.*	*Impedance in Ohms Sec.*	*D.C. Resistance in Ohms Pri.*	*D.C. Resistance in Ohms Sec.*
Input	1.00:45.5	30 C.T.	50,000	14.7	4060
Interstage	3.08:1	100 C.T.	10 C.T.	19	1.27
Output	5.22:1	350 C.T.	4, 12	38	1.45
Output	5.53:1	500 C.T.	4, 8, 16	75.3	3.55
Interstage	3.16:1	500 C.T.	50	59.7	7.9
Output	5.65:1	600 C.T.	4, 8, 16	73.2	3.2
Interstage	1.00:10	500 C.T.	50,000	76.8	5135
Output	6.75:1	825 C.T.	4, 8, 16	74	2.7
Output	9.80:1	1,250	4, 12	132.5	1.4
Interstage	1.00:4	1,200	20,000 C.T.	142	1860
Interstage	1.65:1	1,500	500 C.T.	104	46.5
Output	11.8:1	2,500	4, 16	370	2.3
Interstage	1.00:1.22	5,000 C.T.	7,500 C.T.	650	790
Interstage	1.00:1.41	5,000 C.T.	10,000 C.T.	635	1100
Interstage	1.00:4	5,000 C.T.	80,000 C.T.	573	5740
Output	24.6:1	10,000 C.T.	4, 8, 16	1174	2.6
Interstage	14.0:1	10,000	200 C.T.	1200	33.4
Interstage	2.24:1	10,000	2,000 C.T.	1200	257
Interstage	1.83:1	10,000	3,000 C.T.	1200	385
Output	5.55:1	400 C.T.	11	71.5	1.5
Interstage	3.44:1	500 C.T.	150 C.T.	62	21.2

C.T. = center tap

Transistor alpha and beta

The current amplification factor of a transistor can be expressed in terms of either alpha [α] or beta [β]. The ratio between a change in collector current for a change in emitter current is called alpha, and since alpha is less than unity, you will find it given as a decimal.

When we change emitter current we not only change collector current but base current as well. The ratio of a change in collector current to a change in base current is also used as a measure of the amplification of a transistor and is represented by beta.

The relationship between alpha and beta is shown in these formulas:

$$\beta = \alpha/1 - \alpha$$

or

$$\alpha = 1 - 1/[\beta + 1]$$

Because alpha is a decimal it sometimes makes a problem awkward to handle. For this reason it is sometimes more convenient to give current amplification as beta. Since beta is always in whole numbers it becomes convenient when comparing the current gains of different transistors.

Table 29 on this page supplies common values of alpha and corresponding values for beta. The range of alpha is from 0.5 to 0.9964; that of beta is from 1 to 270.

Examples:

The current gain [alpha] of a transistor is 0.9370. What is its current gain in terms of beta?

Table 29 on page 107 shows that an alpha of 0.9730 corresponds to a beta of 36.

What is the alpha of a transistor if its beta value is 76?

Locate 76 in the column marked *beta*. To the right you will find the value of beta in terms of alpha. Alpha is 0.9870.

Table 29 — Alpha-Beta Conversion

β	α	β	α	β	α
1	0.5000	40	0.9756	79	0.9875
2	0.6666	41	0.9762	80	0.9877
3	0.7500	42	0.9767	81	0.9878
4	0.8000	43	0.9773	82	0.9880
5	0.8333	44	0.9778	83	0.9881

Table 29 — Alpha-Beta Conversion

β	α	β	α	β	α
6	0.8571	45	0.9782	84	0.9882
7	0.8750	46	0.9786	85	0.9884
8	0.8889	47	0.9792	86	0.9885
9	0.9000	48	0.9796	87	0.9886
10	0.9091	49	0.9800	88	0.9888
11	0.9167	50	0.9804	89	0.9889
12	0.9231	51	0.9808	90	0.9890
13	0.9286	52	0.9811	91	0.9891
14	0.9333	53	0.9815	92	0.9892
15	0.9375	54	0.9818	93	0.9894
16	0.9412	55	0.9821	94	0.9895
17	0.9444	56	0.9825	95	0.9896
18	0.9474	57	0.9828	96	0.9897
19	0.9500	58	0.9831	97	0.9898
20	0.9524	59	0.9833	98	0.9899
21	0.9545	60	0.9836	99	0.9900
22	0.9565	61	0.9839	100	0.9901
23	0.9583	62	0.9841	110	0.9909
24	0.9600	63	0.9844	120	0.9917
25	0.9615	64	0.9846	125	0.9921
26	0.9630	65	0.9848	130	0.9931
27	0.9643	66	0.9851	140	0.9932
28	0.9655	67	0.9853	150	0.9933
29	0.9667	68	0.9855	160	0.9938
30	0.9677	69	0.9857	170	0.9942
31	0.9688	70	0.9859	180	0.9945
32	0.9697	71	0.9861	190	0.9948
33	0.9706	72	0.9863	200	0.9952
34	0.9714	73	0.9865	210	0.9954
35	0.9722	74	0.9867	220	0.9956
36	0.9730	75	0.9868	230	0.9958
37	0.9737	76	0.9870	240	0.9960
38	0.9744	77	0.9872	250	0.9962
39	0.9750	78	0.9873	260	0.9963
				270	0.9964

Voltage, Current or Power Ratios and Decibels

Table 30 on pages 109 and 110 supplies voltage, current or power ratios for db ranging from 0.1 to 50. A decibel is a ratio, a means of comparing the relative strengths of a pair of currents, voltages or powers. In itself, a decibel is not indicative of any particular amount of power, voltage or current.

Since the decibel is a comparison unit, and not an absolute value, some reference level must be indicated. A common reference, also called zero level, is 1 milliwatt. Other reference levels can be used, but in any event, the reference should be specified. If 1 milliwatt is the reference, the letter m is added to db, the unit being called the dbm (m for milliwatt). Thus, if an amplifier (assuming equal input and output resistances) has an output of 1 watt, the relationship of the power output to the power input is:

$$db = 10 \log P2/P1$$

or

$$db = 10 \log 1/.001 = 10 \log 1000 = 30 \text{ db}$$

Instead of using the formula, we could have obtained our answer by consulting Table 30. Our power ratio is 1,000 — that is, our output of 1 watt is 1,000 times greater than our reference level of 1 milliwatt. Locate 1,000 under the heading of *power ratio* in the Table. Move to the left and you will see that we have a gain of 30 db.

Examples:

The input voltage to an amplifier is 1 volt, the output is 20 volts. What is the voltage gain of the amplifier in db?

The ratio of the two voltages is 20. The nearest comparable value in the Table is 19.95. The gain is 26 db.

An amplifier is said to have a gain of 20 db. What is its output in watts?

Locate the number 20 in the *db* column in Table 30. Move to the right and you will see that this represents a power ratio of 100. If no power input is given and a reference level of 1 milliwatt is indicated, then the output is 100 milliwatts. If an input power is specified, just multiply the input power by 100 to get the value of output power.

Note that the first two columns in the Table are the reciprocals of the last two columns. Note also that it makes no difference whether you divide the output power of an amplifier by the input, or vice versa. If you put the larger number in the numerator of the db power formula your answer will be a whole number and you will work with

(*continued on page* 111)

Table 30 — Voltage, Current or Power Ratios and Decibels

Voltage or Current Ratio	Power Ratio	— DB +	Voltage or Current Ratio	Power Ratio
1.000	1.000	0	1.000	1.000
0.989	0.977	0.1	1.012	1.023
0.977	0.955	0.2	1.023	1.047
0.966	0.933	0.3	1.035	1.072
0.955	0.912	0.4	1.047	1.096
0.944	0.891	0.5	1.059	1.122
0.933	0.871	0.6	1.072	1.148
0.923	0.851	0.7	1.084	1.175
0.912	0.832	0.8	1.096	1.202
0.902	0.813	0.9	1.109	1.230
0.891	0.794	1.0	1.122	1.259
0.841	0.708	1.5	1.189	1.413
0.794	0.631	2.0	1.259	1.585
0.750	0.562	2.5	1.334	1.778
0.708	0.501	3.0	1.413	1.995
0.668	0.447	3.5	1.496	2.239
0.631	0.398	4.0	1.585	2.512
0.596	0.355	4.5	1.679	2.818
0.562	0.316	5.0	1.778	3.162
0.531	0.282	5.5	1.884	3.548
0.501	0.251	6.0	1.995	3.981
0.473	0.224	6.5	2.113	4.467
0.447	0.200	7.0	2.239	5.012
0.422	0.178	7.5	2.371	5.623
0.398	0.159	8.0	2.512	6.310
0.376	0.141	8.5	2.661	7.079
0.355	0.126	9.0	2.818	7.943
0.335	0.112	9.5	2.985	8.913
0.316	0.100	10	3.162	10.00
0.282	0.0794	11	3.55	12.6
0.251	0.0631	12	3.98	15.9
0.224	0.0501	13	4.47	20.0
0.200	0.0398	14	5.01	25.1
0.178	0.0316	15	5.62	31.6
0.159	0.0251	16	6.31	39.8

Table 30 — Voltage, Current or Power Ratios and Decibels

Voltage or Current Ratio	Power Ratio	— DB +	Voltage or Current Ratio	Power Ratio
0.141	0.0200	17	7.08	50.1
0.126	0.0159	18	7.94	63.1
0.112	0.0126	19	8.91	79.4
0.10000	0.0100	20	10.00	100.0
0.08913	0.0079	21	11.22	125.9
0.07943	0.0063	22	12.59	158.5
0.07079	0.0050	23	14.13	199.5
0.06310	0.00398	24	15.85	251.2
0.05623	0.03162	25	17.78	316.2
0.05012	0.002512	26	19.95	398.1
0.04467	0.001995	27	22.39	501.2
0.03981	0.001585	28	25.12	631.0
0.03548	0.001259	29	28.18	794.3
0.03162	0.001000	30	31.62	1000
0.02818	0.000794	31	35.48	1259
0.02512	0.000631	32	39.81	1585
0.02239	0.000501	33	44.67	1995
0.01995	0.000398	34	50.12	2512
0.01778	0.000316	35	56.23	3162
0.01585	0.000251	36	63.10	3981
0.01413	0.000199	37	70.79	5012
0.01259	0.000158	38	79.43	6310
0.01122	0.000126	39	89.13	7943
0.01000	0.000100	40	100.00	10000
0.00891	0.000079	41	112.2	12590
0.00794	0.000063	42	125.9	15850
0.00708	0.000050	43	141.3	19950
0.00631	0.000040	44	158.5	25120
0.00562	0.000032	45	177.8	31620
0.00501	0.000025	46	199.5	39810
0.00447	0.000020	47	223.9	50120
0.00398	0.000016	48	251.2	63100
0.00355	0.000013	49	281.8	79430
0.00316	0.000010	50	316.2	100000

(*continued from page* 108)

the two columns at the right in the Table. If you use the smaller power value in the numerator, your answer will be a decimal, as indicated in the first two columns in the Table. In either case, your answer in decibels will be the same. If you have an electronic device with a power ratio of 1 to 1,000 or, conversely, 1,000 to 1, the gain or loss in db will be 30 in either case. Some technicians and engineers prefer working with whole numbers and put a minus sign in front of their answer to indicate a loss.

Decibel-Neper conversions

The neper, like the decibel, is a dimensionless unit. While the decibel is derived from the common logarithm, that is, logarithms to the base 10, the neper is used to express the ratio of two power levels using the natural system of logarithms — logarithms to the base e (e = 2.71828). The formula for finding the number of nepers is:

$$\text{nepers} = 1/2 \log_e P2/P1$$

The Table, below, indicates the relationship between decibels and nepers.

Decibels vs Nepers

1 decibel	=	0.1 bel
1 decibel	=	0.1151 neper
1 bel	=	1.151 nepers
1 bel	=	10 decibels
1 neper	=	0.8686 bel
1 neper	=	8.686 decibels

As in the case of decibels, nepers must be used with some reference level if just one value of power, either input or output, is specified.

Table 31 on pages 112 and 113 supplies the conversion between decibels and nepers.

Examples:

An amplifier has a gain of 10 db. What is its gain in nepers?

Locate the number 10 in the *db* column in Table 31. To the right of this number you will find 1.1510 nepers.

Assuming a zero reference level of 1 milliwatt, what is the gain in nepers of an amplifier whose output is 50 milliwatts?

The power ratio in the problem is 50 to 1. Locate the nearest number to this in Table 30. This is shown as 50.1. The gain in db is 17. Now consult Table 31. Locate 17 db in the left-hand column. The number of nepers corresponding to 17 db is 1.9567.

Table 31 — Decibel-Neper Conversions

(n, nepers; db, decibels)

db	n	db	n	db	n
1	0.1151	34	3.9134	67	7.7117
2	0.2302	35	4.0285	68	7.8268
3	0.3453	36	4.1436	69	7.9419
4	0.4604	37	4.2587	70	8.0570
5	0.5755	38	4.3738	71	8.1721
6	0.6906	39	4.4889	72	8.2872
7	0.8057	40	4.6040	73	8.4023
8	0.9208	41	4.7191	74	8.5174
9	1.0359	42	4.8342	75	8.6325
10	1.1510	43	4.9493	76	8.7476
11	1.2661	44	5.0644	77	8.8627
12	1.3812	45	5.1795	78	8.9778
13	1.4963	46	5.2946	79	9.0929
14	1.6114	47	5.4097	80	9.2080
15	1.7265	48	5.5248	81	9.3231
16	1.8416	49	5.6399	82	9.4382
17	1.9567	50	5.7550	83	9.5533
18	2.0718	51	5.8701	84	9.6684
19	2.1869	52	5.9852	85	9.7835
20	2.3020	53	6.1003	86	9.8986
21	2.4171	54	6.2154	87	10.0137
22	2.5322	55	6.3305	88	10.1288
23	2.6473	56	6.4456	89	10.2439
24	2.7624	57	6.5607	90	10.3590
25	2.8775	58	6.6758	91	10.4741
26	2.9926	59	6.7909	92	10.5892
27	3.1077	60	6.9060	93	10.7043
28	3.2228	61	7.0211	94	10.8194
29	3.3379	62	7.1362	95	10.9345
30	3.4530	63	7.2513	96	11.0496
31	3.5681	64	7.3664	97	11.1647
32	3.6832	65	7.4815	98	11.2798
33	3.7983	66	7.5966	99	11.3949
				100	11.5100

Table 31 — Neper-Decibel Conversions

n	*db*	*n*	*db*	*n*	*db*
1	8.686	34	295.324	67	581.962
2	17.372	35	304.010	68	590.648
3	26.058	36	312.696	69	599.334
4	34.744	37	321.382	70	608.020
5	43.430	38	330.068	71	616.706
6	52.116	39	338.754	72	625.392
7	60.802	40	347.440	73	634.078
8	69.488	41	356.126	74	642.764
9	78.174	42	364.812	75	651.450
10	86.860	43	373.498	76	660.136
11	95.546	44	382.184	77	668.822
12	104.232	45	390.870	78	677.508
13	112.918	46	399.556	79	686.194
14	121.604	47	408.242	80	694.880
15	130.290	48	416.928	81	703.556
16	138.976	49	425.614	82	712.252
17	147.662	50	434.300	83	720.938
18	156.348	51	442.986	84	729.624
19	165.034	52	451.672	85	738.310
20	173.720	53	460.358	86	746.996
21	182.406	54	469.044	87	755.682
22	191.092	55	477.730	88	764.368
23	199.778	56	486.416	89	773.054
24	208.464	57	495.102	90	781.740
25	217.150	58	503.788	91	790.426
26	225.836	59	512.474	92	799.112
27	234.522	60	521.160	93	807.798
28	243.208	61	529.846	94	816.484
29	251.894	62	538.532	95	825.170
30	260.580	63	547.218	96	833.856
31	269.266	64	555.904	97	842.542
32	277.952	65	564.590	98	851.228
33	286.638	66	573.276	99	859.914
				100	868.600

TV channels and frequencies

Table 32, below, supplies the channel width, the frequencies in megacycles (mc) of the picture and sound carriers of TV channels. The Table covers VHF channels 2 to 13 (channel 1 has not been assigned) and UHF channels 14 to 83.

The bandwidth of each channel is 6 megacycles, regardless of frequency. In each instance, the video carrier is 1.25 megacycles above the lower edge of the band while the sound carrier is 0.25 megacycle lower than the high-frequency end of the channel. The separation between carriers, video and sound, is 4.5 megacycles.

Example:

What is the sound carrier frequency of channel 16?

Locate channel 16 in the left-hand column. Move to the right and under the heading of *sound carrier* you will find 487.75 mc.

Table 32 — TV-Channels and Frequencies

Channel No.	*Frequency Band (mc)*	*Video Carrier (mc)*	*Sound Carrier (mc)*
(1 not assigned)			
2	54-60	55.25	59.75
3	60-66	61.25	65.75
4	66-72	67.25	71.75
5	76-82	77.25	81.75
6	82-88	83.25	87.75
7	174-180	175.25	179.75
8	180-186	181.25	185.75
9	186-192	187.25	191.75
10	192-198	193.25	197.75
11	198-204	199.25	203.75
12	204-210	205.25	209.75
13	210-216	211.25	215.75
14	470-476	471.25	475.75
15	476-482	477.25	481.75

Table 32 — TV-Channels and Frequencies

Channel No.	Frequency Band (mc)	Video Carrier (mc)	Sound Carrier (mc)
16	482-488	483.25	487.75
17	488-494	489.25	493.75
18	494-500	495.25	499.75
19	500-506	501.25	505.75
20	506-512	507.25	511.75
21	512-518	513.25	517.75
22	518-524	519.25	523.75
23	524-530	525.25	529.75
24	530-536	531.25	535.75
25	536-542	537.25	541.75
26	542-548	543.25	547.75
27	548-554	549.25	553.75
28	554-560	555.25	559.75
29	560-566	561.25	565.75
30	566-572	567.25	571.75
31	572-578	573.25	577.75
32	578-584	579.25	583.75
33	584-590	585.25	589.75
34	590-596	591.25	595.75
35	596-602	597.25	601.75
36	602-608	603.25	607.75
37	608-614	609.25	613.75
38	614-620	615.25	619.75
39	620-626	621.25	625.75
40	626-632	627.25	631.75
41	632-638	633.25	637.75
42	638-644	639.25	643.75
43	644-650	645.25	649.75
44	650-656	651.25	655.75
45	656-662	657.25	661.75
46	662-668	663.25	667.75
47	668-674	669.25	673.75
48	674-680	675.25	679.75
49	680-686	681.25	685.75
50	686-692	687.25	691.75

Table 32 — TV-Channels and Frequencies

Channel No.	Frequency Band (mc)	Video Carrier (mc)	Sound Carrier (mc)
51	692-698	693.25	697.75
52	698-704	699.25	703.75
53	704-710	705.25	709.75
54	710-716	711.25	715.75
55	716-722	717.25	721.75
56	722-728	723.25	727.75
57	728-734	729.25	733.75
58	734-740	735.25	739.75
59	740-746	741.25	745.75
60	746-752	747.25	751.75
61	752-758	753.25	757.75
62	758-764	759.25	763.75
63	764-770	765.25	769.75
64	770-776	771.25	775.75
65	776-782	777.25	781.75
66	782-788	783.25	787.75
67	788-794	789.25	793.75
68	794-800	795.25	799.75
69	800-806	801.25	805.75
70	806-812	807.25	811.75
71	812-818	813.25	817.75
72	818-824	819.25	823.75
73	824-830	825.25	829.75
74	830-836	831.25	835.75
75	836-842	837.25	841.75
76	842-848	843.25	847.75
77	848-854	849.25	853.75
78	854-860	855.25	859.75
79	860-866	861.25	865.75
80	866-872	867.25	871.75
81	872-878	873.25	877.75
82	878-884	879.25	883.75
83	884-890	885.25	889.75

Conversion of electronics units

Formulas in electronics use basic units — units such as the volt, ohm, ampere, farad, henry. However, problems invariably supply information in terms of multiples or submultiples of these units. Thus, before any solution can be attempted, it is necessary to convert multiples or submultiples to basic units.

Quite often the numbers used in formulas will be very large whole numbers or large decimals. In either case, it is highly advantageous to be able to use powers of ten and to be familiar with the rules for dividing and multiplying numbers using exponents. Table 33, below, shows the method of expressing small and large numbers using powers of ten.

Table 33 — Powers of Ten

10^0	= 1	10^0	= 1
10^1	= 10	10^{-1}	= .1
10^2	= 100	10^{-2}	= .01
10^3	= 1,000	10^{-3}	= .001
10^4	= 10,000	10^{-4}	= .0001
10^5	= 100,000	10^{-5}	= .00001
10^6	= 1,000,000	10^{-6}	= .000001
10^7	= 10,000,000	10^{-7}	= .0000001
10^8	= 100,000,000	10^{-8}	= .00000001
10^9	= 1,000,000,000	10^{-9}	= .000000001
10^{10}	= 10,000,000,000	10^{-10}	= .0000000001
10^{11}	= 100,000,000,000	10^{-11}	= .00000000001
10^{12}	= 1,000,000,000,000	10^{-12}	= .000000000001

Table 34 — Symbols and Prefixes for Powers of Ten

Power of ten	*Prefix*	*Symbol*
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Symbols and prefixes for powers of ten

Numbers have names. The prefixes given in Table 34 will be helpful in identifying particular values of powers of ten. Thus, a gigacycle (prefix giga) corresponds to 10^9. Table 34 also supplies the symbols for various powers of ten.

Table 35 supplies data on the conversion of electronic units. Table 36, page 121, gives the abbreviations for electronic units; Table 37, page 122, gives numerical prefixes.

Table 35 — Conversion of Electronic Units

Multiply	*By*	*To Convert To*
ampere turns	1.257	gilberts
amperes	10^{12}	micromicroamperes
amperes	10^{6}	microamperes
amperes	10^{3}	milliamperes
centimeters	10	millimeters
cycles	10^{-6}	megacycles
cycles	10^{-3}	kilocycles
cycles	10^{9}	gigacycles (kilomegacycles)
degrees	60	minutes
farads	10^{12}	picofarads (micromicrofarads)
farads	10^{6}	microfarads
farads	10^{3}	millifarads
gausses	1	lines per square centimeter
gausses	6.452	lines per square inch
henrys	10^{6}	microhenrys
henrys	10^{3}	millihenrys
horsepower	.7457	kilowatts
horsepower	745.7	watts
joules	1	watt-seconds
kilocycles	10^{3}	cycles
kilocycles	10^{-3}	megacycles
kilocycles	10^{6}	gigacycles
kilovolt-amperes	10^{3}	volt-amperes
kilovolts	10^{3}	volts
kilowatts	10^{3}	watts

Table 35 — Conversion of Electronic Units

Multiply	*By*	*To Convert To*
kilowatts	1.341	horsepower
kilowatt-hours	3.6×10^6	joules
lines per square centimeter	1	gausses
lines per square centimeter	6.452	lines per square inch
megacycles	10^6	cycles
megacycles	10^3	kilocycles
megawatts	10^{-6}	watts
megohms	10^6	ohms
meters	10^2	centimeters
meters	3.281	feet
meters	39.37	inches
meters	10^3	millimeters
mhos	10^6	micromhos
mhos	10^3	millimhos
microamperes	10^{-6}	amperes
microamperes	10^{-3}	milliamperes
micromicroamperes	10^6	microamperes
microfarads	10^{-6}	farads
microfarads	10^6	picofarads (micromicrofarads)
microhenrys	10^{-6}	henrys
microhenrys	10^{-3}	millihenrys
micromhos	10^{-6}	mhos
micromicrofarads (picofarads)	10^{-12}	farads
micromicrofarads	10^{-6}	microfarads
micromicro-ohms	10^{-12}	ohms
microvolts	10^{-3}	millivolts
microvolts	10^{-6}	volts
microwatts	10^{-6}	watts
microwatts	10^{-3}	milliwatts
milliamperes	10^{-3}	amperes
milliamperes	10^3	microamperes
millihenrys	10^{-3}	henrys

Table 35 — Conversion of Electronic Units

Multiply	*By*	*To Convert To*
millimeters	10^{-3}	meters
millimeters	10^{-1}	centimeters
millimhos	10^{-3}	mhos
millivolts	10^{-3}	volts
millivolts	10^{3}	microvolts
millivolts	10^{-6}	kilovolts
milliwatts	10^{-3}	watts
milliwatts	10^{3}	microwatts
milliwatts	10^{-9}	megawatts
mils	10^{-3}	inches
minutes	60	seconds
minutes	1/60	degrees
ohms	10^{-3}	kilohms
ohms	10^{-6}	megohms
picofarads (see micromicrofarads)		
radians	57.3	degrees
seconds	1/3600	degrees
seconds	10^{3}	milliseconds
seconds	10^{6}	microseconds
seconds	1/60	minutes
square centimeters	$1{,}973 \times 10^{2}$	circular mils
square inches	$1{,}273 \times 10^{3}$	circular mils
square mils	1.273	circular mils
volt-amperes	1/1,000	kilovolt-amperes
volts	10^{6}	microvolts
volts	10^{3}	millivolts
volts	10^{-3}	kilovolts
watt-hours	36×10^{2}	joules
watt-seconds	1	joules
watts	10^{6}	microwatts
watts	10^{3}	milliwatts
watts	10^{-3}	kilowatts
watts	10^{-6}	megawatts

Table 36 — Electronic Units and their Abbreviations

Capacitance	Symbol C
	f = farad μf = microfarad $\mu\mu$f = picofarad (micromicrofarad)
Frequency	Symbol f
	cps = cycles per second kc or kcs = kilocycles per second mc or mcs = megacycles per second
Inductance	Symbol L
	h = henry mh = millihenry μh = microhenry
Resistance	Symbol R
	ω = ohm Kω = kilohm Mω = megohm
Time	Symbol t
	sec = second msec = millisecond μsec = microsecond
Current	Symbol I
	a = ampere ma = milliampere μa = microampere
Voltage	Symbol E
	v = volt mv = millivolt μv = microvolt

Table 37 — Numerical Prefixes

Number	*Greek prefix*	*Latin prefix*
½	hemi-	semi-
1	mono- or mon-	uni-
1½	———	sesqui-
2	di-	bi-; duo-
3	tri-	tri- or ter-
4	tetra- or tetr-	quadri- or quadr-
5	penta- or pent-	quinque- or quinqu-
6	hexa- or hex-	sexi- or sex-
7	hepta- or hept-	septi- or sept-
8	octa- or oct- or octo-	octo-
9	ennea- or enne-	nona-; novem-
10	deca- or dec-	decem-
11	hendeca- or hendec-	undeca- or undec-
12	dodeca- or dodec-	duodec-
13	trideca- or tridec-	tredec-
14	tetradeca- or tetradec-	quatuordec-
15	pentadeca- or pentadec-	quindec-
16	hexadeca- or hexadec-	sextodec-
17	heptadeca- or heptadec-	septendec-
18	octadeca- or octadec-	octodec-
19	nonadeca- or nonadec-	novemdec-
20	eicosa- or eicos-	viginti-
21	heneicosa- or heneicos-	
22	docosa- or docos-	
23	tricosa- or tricos-	
24	tetracosa- or tetracos-	
25	pentacosa- or pentacos-	
26	hexacosa- or hexacos-	
27	heptacosa- or heptacos-	
28	octacosa- or octacos-	
29	nonacosa- or nonacos-	
30	triaconta- or triacont-	triginti-
31	hentriaconta- or hentriacont-	
32	dotriaconta- or dotriacont-	
40	tetraconta- or tetracont-	quadragin-
50	pentaconta- or pentacont-	quinquagin-
60	hexaconta- or hexacont-	sexagin-

Table 38 — Electronic Abbreviations

Technical abbreviations appear in electronics text material, in circuit diagrams, in reports and in magazine articles. There is no industry-wide style standard. The best that can be hoped for is that a selected style will be consistent throughout a book, report or article. Abbreviations may be in lower-case, capital letters or some combination of both. Abbreviations may or may not have points (periods). Points are desirable where the abbreviation may be mistaken for a word.

Abbreviation	*Term*
A	
a or amp	ampere (s)
Å	Ångström unit
abc	automatic base compensation
acc	automatic chroma control
adj	adjacent; adjustment
adf	automatic direction finder
af	audio frequency
afc	automatic frequency control
aft	audio-frequency transformer
agc	automatic gain control
ah	ampere-hour
am	amplitude modulation
amp	ampere (s)
ampl	amplifier
anl	automatic noise limiter
ant	antenna
antilog	antilogarithm
apc	automatic phase control
ASA	American Standards Association
atten	attenuator
autotrans	autotransformer
avc	automatic volume control
ave	automatic volume expansion
AWG	American wire gage

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
B	
b	bel
b or base	base (transistor)
B	magnetic flux density
bal mod	balanced modulator
balun	balanced-to-unbalanced transformer
batt	battery
bcd	binary coded decimal
bci	broadcast interference
bcl	broadcast listener
bfo	beat-frequency oscillator
bit (s)	binary digit (s)
bo	Barkhausen oscillation
bp	bandpass
bto	blocking-tube oscillator
C	
c	centi— (one-hundredth; 10^{-2})
c, cap	capacitor (or capacitance)
C	Centigrade
calib	calibrate
cath (K on diagram)	cathode
cath foll	cathode follower
cc	cotton covered (wire)
ccw	counterclockwise
cemf	counter electromotive force
cent	centering
c_{gk}	grid-cathode capacitance (tube)
c_{gp}	grid-plate capacitance (tube)
cgs	centimeter-gram-second
ch	choke
chan	channel

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
chg	charge
cir mil (s)	circular mil (s)
ckt brkr	circuit breaker
cm	centimeter
coax	coaxial cable
colog	cologarithm
com	common
cond	conductor
conn	connection
cont	control
counter emf; cemf	counter electromotive force
conv	convergence; converter
cos	cosine
cosh	hyperbolic cosine
cot	cotangent
cps	cycles per second
c-r	cathode-ray
cro	cathode-ray oscilloscope
crt	cathode-ray tube
csc; cosc	cosecant
ct	center tap
cw	clockwise

D

d	diode; deci— (one-tenth; 10^{-1})
db	decibel
dblr	doubler
dbm	decibels referred to 1 milliwatt in 600 ohms
dc	direct current
dc rest	dc restorer
dcc	double cotton covered (wire)
defl	deflection

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
deg	degree (angle)
demod	demodulator
det	detector
dielec	dielectric
diff	differentiator
disch	discharge
discrim	discriminator
dk	deka— (ten; 10^1)
dpdt	double-pole, double-throw (switch)
dpst	double-pole, single-throw (switch)
dsc	double silk covered (wire)
dx	distance
dyn	dynamic
E	
e	emitter (transistor); voltage; electronic charge
ec	enamel covered
eco	electron-coupled oscillator
ehf	extremely high frequencies (30 gc to 300 gc)
EIA	Electronic Industries Association
elec	electric; electrolytic
elect	electrode
emf	electromotive force
emu	electromagnetic unit (s)
enam	enameled (wire)
ep	extended play
equiv	equivalent
erase hd	erase head
erf	error function
erp	effective radiated power
esu	electrostatic unit (s)
ev	electron volt (s)
ext	external or extension

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
F	
f	Fermi (10^{-15} m)
f or freq	frequency
F	Fahrenheit
F	farad (s)
FCC	Federal Communications Commission
fil (f in diagrams)	filament
fm	frequency modulation
foll	follower (-ing)
fone	headphones; earphones (see also phone)
FS	Fourier series
G	
g	gram; grid (in diagrams); conductance
gb	gilberts
gc	gigacycles (kilomegacycles)
gca	ground-controlled approach
gdo	grid-dip oscillator
gen	generator
gnd	ground
H	
H	magnetic intensity
h	henry (ys); hecto or hekto (one hundred; 10^2)
ham	radio amateur operator
hd	head
hf	high frequency
hi pot	high potential
hor or horiz	horizontal
hp	horsepower
hr	hour
htr (in diagrams)	heater
hv	high voltage

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
I	
i	current (instantaneous value)
ic	internal connection (in tubes)
icw	interrupted continuous waves
if or i.f.	intermediate frequency
ift	intermediate-frequency transformer
ils	instrument landing system
im	intermodulation
in	inch; input
int	integrator
I_p	plate current
ips	inches per second
J	
j; J	joule
jb	junction box
jct	junction
K	
K	numerical constant
k	kilo; thousand; 10^3
kc	kilocycle
kcs	kilocycles per second
kg	kilogram
kv	kilovolt (s)
kva	kilovolt-ampere
kvar	reactive kilovolt amperes
kw	kilowatt
kwhr	kilowatt-hour
L	
L	coil; inductor; inductance
lf	low frequency
lin	linearity
ln; $\log_e$	Napierian logarithm

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
lm	limiter
log; $\log_{10}$	common logarithm
$\log^{-1}$	antilogarithm
ls	limit switch
M	
m	milli (10^{-3}); meter; mutual inductance
μ	micro (10^{-6})
μa	microampere
ma	milliampere
max	maximum
mc	megacycle
md	mean deviation
mcs	megacycles per second
meg	megohm
mega	million; (10^{6})
mev	million electron volts
μf	microfarad
mf	medium frequencies (300 kc to 3,000 kc)
mh	millihenry (ys)
μh	microhenry (ys)
micro	one-millionth; (10^{-6})
micromicro	one-millionth of a millionth; (10^{-12}) (see also pico)
mike	microphone
min	minimum
mks	meter-kilogram-second
μμ	micromicro (10^{-12}) (same as pico)
μμf	micromicrofarad (same as picofarad)
mmf	magnetomotive force
mod	modulation; modulator; modulus
mpx	multiplex
μsec	microsecond
msec	millisecond

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
mult	multiplier
μv	microvolt
mv	multivibrator; millivolt
mva	megavolt-ampere
mvb	multivibrator
mvc	manual volume control
μv/m	microvolts per meter
μw	microwatt
mw	megawatt
mwh	megawatt-hour
my	myria; (ten thousand; 10^4)
N	
n	nano; (10^{-9})
nbfm	narrow-band fm
nc	normally-closed (switch or relay); neutralizing capacitor
ne	neon
neg	negative; minus
net	network
no	normally open (switch or relay)
npn	negative-positive-negative (transistor)
nvr	no voltage release
O	
o/v	ohms per volt
osc	oscillator
out	output
P	
p	power; pole; plate (on diagrams); pico (10^{-12})
pa	public address; power amplifier
pc	photocell
pd	potential difference

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
pent	pentode
perm	permanent
pf	power factor; picofarad (micromicrofarad)
phone (s) (or fone)	headphones; earphones
photo mult	photomultiplier
pico	formerly designated as micromicro (10^{-12})
pix	picture
pl	pilot lamp
pm	permanent magnet (speaker); phase modulation; pulse modulation
pnp	positive-negative-positive (transistors)
pos	positive; plus
pot	potentiometer; potential
pp	peak-to-peak; pushpull
pps	pulses per second
ppi	plan-position indicator (radar)
preamp	preamplifier
prf	pulse repetition frequency
pri	primary
pt	phototube

Q

Q	reactance-resistance ratio; transistor; coulomb
quad	quadrature

R

r	resistance; resistor
rc	resistance-capacitance
r-c	radio control
rcdg	recording
rcdr	recorder
rect	rectifier
reg	regulator
regen	regeneration

Table 38 — Electronic Abbreviations

Abbreviation	Term
rf	radio frequency
rfc	radio-frequency choke
rft	radio-frequency transformer
rheo	rheostat
r-l	resistance-inductance
rms	root-mean-square
ry	relay
ry, nc	relay, normally closed
ry, no	relay, normally open

S

Abbreviation	Term
s or sw	switch
scc	single-cotton covered (wire)
scope	oscilloscope
scr	silicon-controlled rectifier
sec	second; secondary; secant
sech	hyperbolic secant
sel (rect)	selenium (rectifier)
sels	selsyn
sep	separator
sg	screen grid
sig	signal
sinh	hyperbolic sine
sld	solenoid
s/n	signal-to-noise ratio
sp	single-pole
spdt	single-pole, double-throw
spdtdb	single-pole, double-throw, double-break
spdtncdb	single-pole, double-throw, normally-closed, double break
spdtno	single-pole, double-throw, normally-open
spdtnodb	single-pole, double-throw, normally-open, double-break

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
spstnc	single-pole, single-throw, normally-closed
spstno	single-pole, single-throw, normally-open
sq	square
ssb	single sideband
ssc	single silk covered (wire)
sup	suppressor
superhet	superheterodyne
swl	short-wave listener
swr	standing-wave ratio
sync	synchronization
T	
t	transformer; trimmer capacitor; tera; (10^{12})
tan	tangent
tanh	hyperbolic tangent
teleg	telegraph; telegram
term	terminal
TI	ampere turns
tptg	tuned-plate; tuned-grid
tr	transmit-receive
trans	transformer
trf	tuned-radio frequency
trig	trigger
tsf	telegraphie sans fil (wireless telegraphy)
tv	television
tvi	television interference
U	
uhf	ultra-high frequencies (300 to 3,000 mc)
UL	Underwriters' Laboratories, Inc.
V	
v	volt (s); transistor
va	voltampere; voltage amplifier

Table 38 — Electronic Abbreviations

Abbreviation	*Term*
vac; vdc	volts ac, dc
var	variable; reactive volt-amperes; varistor
vc	voice coil
vers	versed sine
vert	vertical
vfo	variable frequency oscillator
vhf	very high frequencies (30 to 300 mc)
vlf	very low frequencies (below 30 kc)
v/m	volts per meter
vol	volume
vom	volt-ohm-milliammeter; volt-ohmmeter
vr	voltage regulator (tube)
vt or v	tube
vtvm	vacuum-tube voltmeter
vu	volume unit

W

w	watt (s)
whr	watt-hour

X

x	reactance
X_C	capacitive reactance
X_L	inductive reactance
xformer	transformer
xmission	transmission
xtal	crystal

Z

z	impedance

Color codes

Resistors and capacitors can be identified by using the color code recommended by the Electronics Industries Association (EIA). Each color indicates a number.

Table 39 — The Basic Color Code

Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9

These colors are used to indicate the values of resistors and capacitors. They are also used to represent tolerance. Thus, brown is a tolerance of ±1%, red is ±2%, orange is ± 3% and yellow is ±4%. However, gold is used for ±5%, silver for ±10%. Absence of color means ±20%.

Table 40 — Color Code for Resistors

Color	*First Digit*	*Second Digit*	*Multiplier*	*Tolerance (±)*
Black	—	0	1	—
Brown	1	1	10	1%
Red	2	2	100	2%
Orange	3	3	1,000	3%
Yellow	4	4	10,000	4%
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7	10,000,000	
Gray	8	8	100,000,000	
White	9	9	1,000,000,000	
Silver				10%
Gold				5%
No color				20%

Resistor color code

The value of a resistor is coded by rings of color placed at one end. The first color is the first significant figure or digit of the resistance value. The second color is the second significant figure or digit of the resistance value. The third color, known as the decimal multiplier, represents the number of zeros which follow the first two digits.

Resistors having a tolerance of ±20% have only three bands of color. A fourth color, if used, is the tolerance. This fourth color is either silver or gold. Table 40 is the resistor color code.

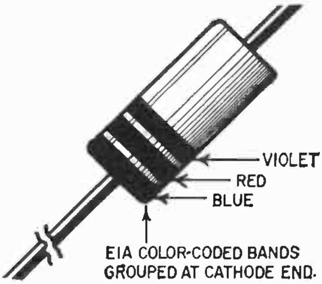
Example:

What is the value of a resistor that is color coded yellow, violet and orange?

The first color yellow, is 4. The second color, violet is 7. The final color, orange, is 3 and represents three zeros. The resistance is 47,000 ohms.

Diode color code

Crystal diodes are marked according to the EIA color code given in Table 39. The color bands start from the *cathode* end and represent



Crystal diodes are marked according to the same basic color code used for resistors. See Table 39 on page 135.

the digits following the 1N prefix. For example, the diode in the drawing is a 1N627.

Capacitors

Capacitors are named after some particular physical characteristic. Thus, a mica capacitor has a mica dielectric; a disc capacitor is so-called because of its shape. The color coding of a capacitor may supply information about some or all of the following: amount of capacitance; voltage breakdown rating; tolerance; temperature coefficient; insulation resistance; maximum capacitance drift. The values assigned to each of the colors in capacitor color codes are the same as for resistors.

Information about capacitor characteristics does not always make use of a color coding system. If the capacitor is large enough, the value of capacitance and other information may be printed or stamped on the body of the capacitor. Where the size of the capacitor does not permit this, the physical dimensions of the capacitor may be used to represent the value of capacitance. In the case of subminiature units, where the size of the capacitor may not be much greater than the leads coming out of it, a method of capacitor identification is to put the capacitors into a small envelope and then to put pertinent information on the envelope itself.

Color coles for capacitors

Color codes are used for paper, mica and ceramic units. The terms used here refer to the capacitor dielectric. The amount of information supplied by a color code depends on how elaborate the coding system may be. Colors are used to indicate capacitance, dc working voltage rating, tolerance, temperature coefficient, capacitance drift. Color codes always refer to capacitance in pf (picofarads or micromicro-farads).

Mica capacitors

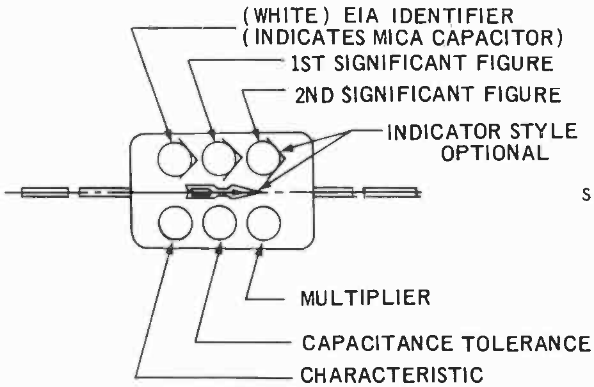
The capacitance and other characteristics of mica capacitors is indicated through a color dot arrangement. The number of color dots used have ranged from three to nine. The present arrangement is a standard six- or nine-dot system.

Table 41 supplies the characteristics, capacitance and tolerance of mica capacitors using the six-dot color system. The multiplier is the factor by which the two significant figures are multiplied to yield the nominal capacitance.

Table 41 — Standard Six-Dot Color System

		Capacitance (pf)		
Color	Characteristic	*1st & 2nd Significant Figures*	*Multiplier*	*Capacitance Tolerance (±)*
Black		0	1	20%
Brown	B	1	10	1%
Red	C	2	100	2%
Orange	D	3	1000	
Yellow	E	4	10000	
Green	F	5		5%
Blue		6		
Violet		7		
Gray		8		
White		9		
Gold			0.1	½%
Silver			0.01	10%

The characteristic, shown in column 2 of Table 41 and identified by the letters B, C, D, E and F, refers to the temperature coefficient



Six-dot coding for mica capacitors.

of capacitance and the maximum amount of capacitance drift. These characteristics are given in Table 42.

Table 42 — Mica Capacitor Characteristics

Characteristic	*Temperature Coefficient of Capacitance (ppm/°C)*	*Maximum Capacitance Drift*
B	Not specified	Not specified
C	±200	±(0.5% +0.5 pf)
D	±100	±(0.3% +0.1 pf)
E	−20 to +100	±(0.1% +0.1 pf)
F	0 to + 70	±(0.05% +0.1 pf)

Note that Table 41 does not include the dc working voltage. The voltage rating depends on the case size and ranges from 100 to 1,000 volts dc. However, in the nine-dot system, the dc working voltage is given on one side of the capacitor. The front side of a capacitor using the nine-dot system is exactly the same as one using the six-dot arrangement. On the reverse side of a nine-dot capacitor, however, there are three additional dots, the first indicating the dc working voltage, the second the operating temperature range. The indicator dot on the reverse side is optional.

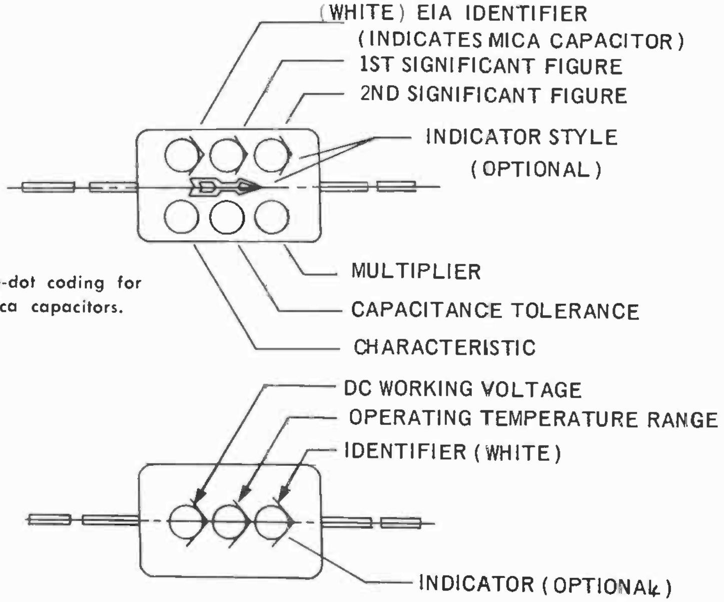
Table 43 supplies all the pertinent information for mica capacitors using the nine-dot system. The characteristic in column 2 is the same as shown in Table 42.

Example:

What is the capacitance of a mica capacitor using a six-dot system, whose upper three dots read white, red and violet and whose lower three dots read brown, black and brown?

Table 43 — Standard Nine-Dot Color System

Color	Characteristic	Capacitance (pf) 1st & 2nd Significant Figures	Multiplier	Tolerance (%)	DC Working Voltage	Operating Temperature Range
Black		0	1	±20%		
Brown	B	1	10	±1%	100	
Red	C	2	100	±2%		−55° to +85°C
Orange	D	3	1000		300	
Yellow	E	4	10000			−55° to +125°C
Green	F	5		±5%	500	
Blue		6				
Violet		7				
Gray		8				
White		9				
Gold			0.1	±½%	1000	
Silver			0.01	±10%		

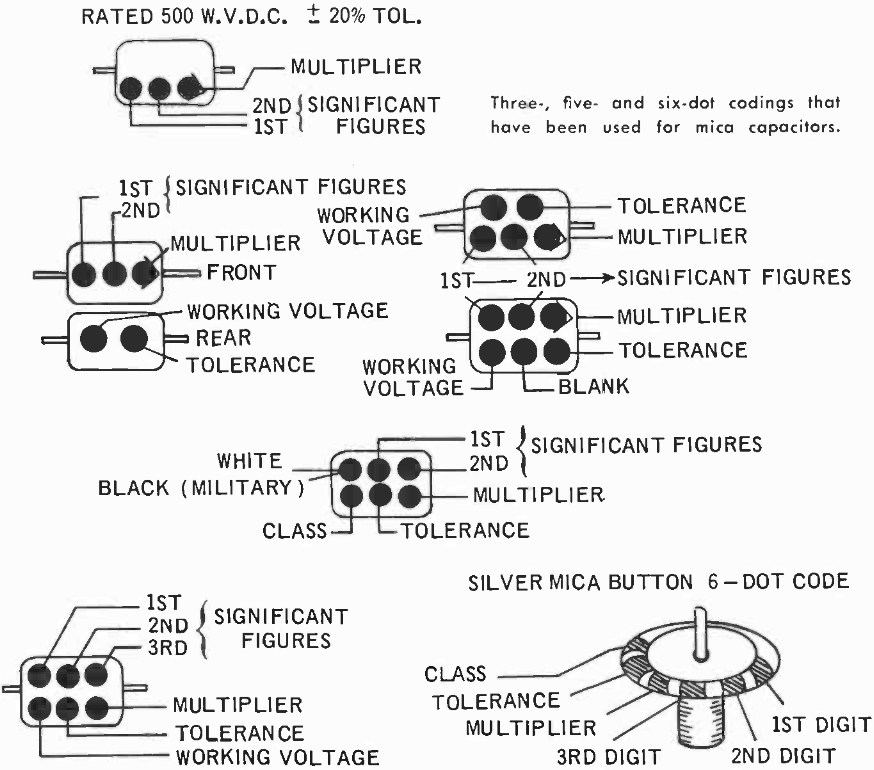


Nine-dot coding for mica capacitors.

The first dot, white, tells us that the capacitor is a mica unit. The next two colors, red and violet, represent the first and second significant figures of capacitance. Red is 2 and violet is 7. The brown dot in the multiplier position has a value of 10. Multiplying 27 by 10 gives 270 pf, the total value of capacitance. The brown dot at the bottom left is the characteristic. This characteristic is B, and Table 42 tells us that this characteristic is not specified . . . that is, no information is available on the temperature coefficient or the capacitance drift. The black dot at the bottom center is the capacitance tolerance. Table 43 shows that we have a capacitor that is ±20% unit.

Other mica capacitors

A variety of color codes, ranging from three to six dots, have been used, and while these codes are obsolete, capacitors containing such



Three-, five- and six-dot codings that have been used for mica capacitors.

marking will be encountered. The drawings show the dot arrangements and the significance of each dot. In each case, though, the colors have the same value that was given in Table 40.

Capacitors, both mica and other types, are sometimes produced to manufacturers' or military specifications, in which case the EIA arrangement may or may not be followed. The only alternative, then, is to check the capacitor on a bridge. While this will yield the capacitance value, it supplies no information on other characteristics.

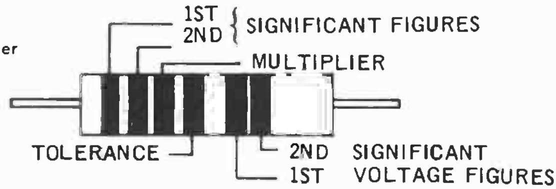
Molded paper tubular capacitors

These capacitors can have five or six color bands. To read the value of capacitance, hold the unit so that the color bands are grouped toward the left. Table 44 supplies the color code.

Table 44 — Code for Molded Paper Tubulars

Color	*Digits of Capacitance (pf)* 1st Significant Figure	2nd Significant Figure	*Multiplier*	*Tolerance %*	*DC Working Voltage*
Black	0	0	1	±20	—
Brown	1	1	10	—	100
Red	2	2	100	—	200
Orange	3	3	1,000	±30	300
Yellow	4	4	10,000	—	400
Green	5	5	—	—	500
Blue	6	6	—	—	600
Violet	7	7	—	—	700
Gray	8	8	—	—	800
White	9	9	—	—	900
Gold	—	—	—	—	1,000
Silver	—	—	—	±10	—

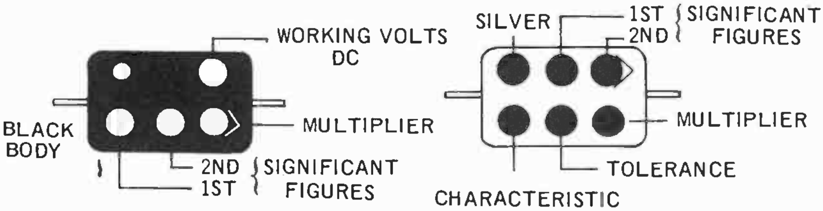
The difference between a five-color and a six-color band is in the voltage rating. A capacitor with five colors follows the voltage rating given in Table 44. If the capacitor has six colors, the last two colors [colors at the right when holding the capacitor with the maximum number of bands toward the left] are both used for the voltage rating. Multiply the value represented by these two colors by 100, or move the decimal point two places to the right. Thus, if the last two colors are brown [1] and red [2], the voltage rating is 12 × 100 or 1,200 volts. If the capacitor has a rating of 1,000 volts, or less, then only five colors are used, the end color representing the voltage indicated in Table 44.



Coding for tubular paper capacitors.

Molded paper flat [rectangular] capacitors

These capacitors use the same code as that given in Table 44. Unlike the molded tubular paper type capacitors, the rectangular units



Coding for molded flat paper capacitors.

may or may not carry color coding indicating the working voltage. If the voltage rating is not indicated, then the voltage rating may be determined by measuring the dimensions of the unit.

Examples:

A molded paper tubular capacitor has the following five colors: red, black, yellow, silver, blue. What is its capacitance, tolerance and voltage rating?

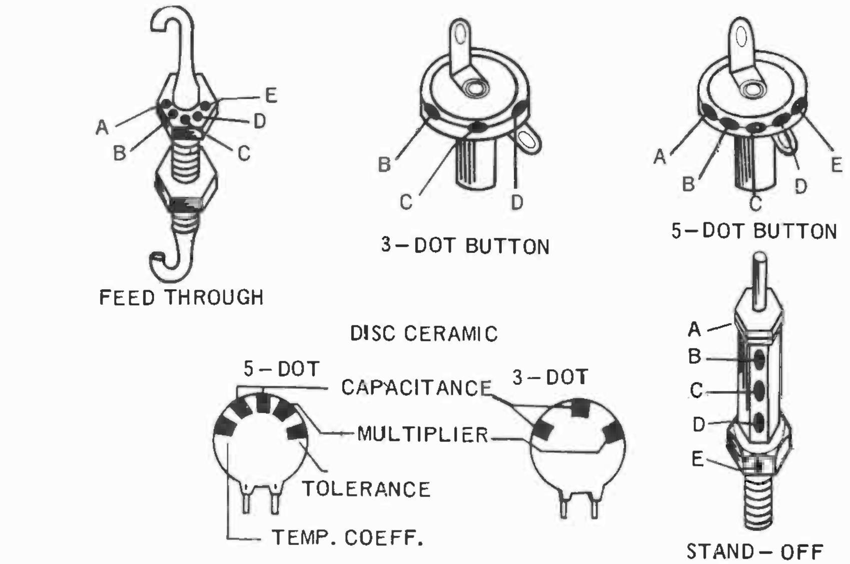
The first two colors are capacitance digits. According to Table 44 red is 2 and black is 0. Put a decimal point after these two numbers and you will have the number 20. Our third color, yellow, is our multiplier. The multiplier tells us how many places we must move the decimal point to the right. Yellow is 10,000. This means we must multiply 20 by 10,000. We get the same result, faster, just by moving the decimal point to the right by four places. Our capacitance value, then, is 200,000 pf, or 0.2 μf. The fourth color band is silver. Table 44 shows that this represents a tolerance of $\pm$10%. Our final color, blue, gives the voltage rating of 600 volts.

A molded paper tubular capacitor has the following six colors: brown, red, red, silver, red, brown. What is its capacitance, tolerance, and voltage rating?

Brown = 1 red = 2 the multiplier, red, = 00
Capacitance = 1200 pf Silver = $\pm$10% tolerance
Fifth and sixth colors are red-brown = 21
Multiply 21 $\times$ 100 and voltage rating is 2,100 volts

Ceramic capacitors

Ceramic capacitors have an interesting variety of styles. They are available in tubular form, as disc types, as feed-through, as dot button, as stand-off units. They are available in both radial and axial lead arrangements. These capacitors may be color coded with bands,



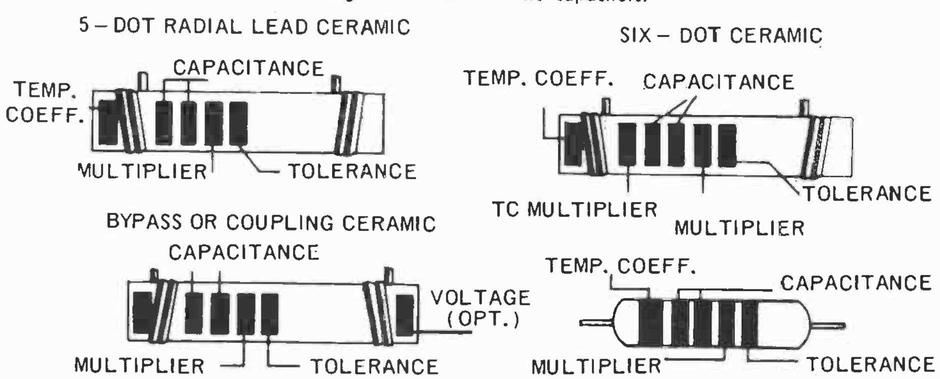
Miscellaneous types of ceramic capacitors. A-temperature coefficient; B-first significant figure of capacitance; C-second significant figure of capacitance; D-decimal multiplier; E-tolerance.

with a combination of bands and dots, or by dots alone. The number of dots may range from three to six.

Tubular ceramic capacitors

Tubular ceramics use bands of color or a combination of bands and dots with a system employing either five or six colors. Tables 45

Coding for tubular ceramic capacitors.



and 46 supply the meanings of the colors for the five-and six-color systems.

Table 45 — Tubular Ceramic Capacitor Five-Color System

First color	Temperature Coefficient of Capacitance
Second color	First significanct figure of capacitance
Third color	Second significant figure of capacitance
Fourth color	Decimal multiplier of capacitance
Fifth color	Tolerance of capacitance

Table 46 — Tubular Ceramic Capacitor Six-Color System

First color	Significant figure of temperature coefficient of capacitance
Second color	Multiplier to apply to significant figure of temperature coefficient
Third color	First significant figure of capacitance
Fourth color	Second significant figure of capacitance
Fifth color	Decimal multiplier of capacitance
Sixth color	Tolerance of capacitance

Table 47 supplies the coding for ceramic dielectric capacitors. This Table can be used for ceramic capacitors having either five or six colors.

Table 47 — Code for Ceramic Dielectric Capacitors

Color	*1st and 2nd Signi-nificant Figure of Capaci-tance*	*Decimal Multiplier of Capacitance*	*Tolerance of Capacitance* Nominal 10 pf or Less	*Tolerance of Capacitance* Nominal Over 10 pf
Black	0	1	±2.0 pf	±20%
Brown	1	10	±0.1 pf	±1%
Red	2	100		±2%
Orange	3	1000		±3%
Yellow	4	10000		
Green	5		±0.5 pf	±5%
Blue	6			
Violet	7			
Gray	8	0.01	±0.25 pf	
White	9	0.1	±1.0 pf	±10%

Table 47 — Code for Ceramic Dielectric Capacitors (continued)

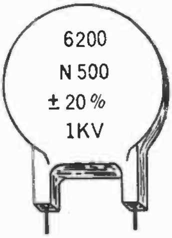
Color	*Temperature Coefficient of Capacitance (5 Dot System)*	*Significant Figure of Temperature Coefficient of Capacitance (6 Dot System)*	*Multiplier to Apply to Significant Figure of Temperature Coefficient (6 Dot System)*
Black	0 pts/mln/°C	0.0	—1
Brown	— 33 pts/mln/°C	—	—10
Red	— 75 pts/mln/°C	1.0	—100
Orange	—150 pts/mln/°C	1.5	—1000
Yellow	—220 pts/mln/°C	2.2	—10000
Green	—330pts/mln/°C	3.3	+1
Blue	—470 pts/mln/°C	4.7	+10
Violet	—750 pts/mln/°C	7.5	+100
Gray	General Purpose	General Purpose	+1000
White	General Purpose		+10000

Miniature molded ceramics

These tiny capacitors may be marked according to a coding system set up by each manufacturer. In a four-color unit, the first two colors represent the first and second significant figures of capacitance, the third color is the multiplier and the fourth color is the tolerance.

Other capacitor markings

Not all capacitors use codes. Some are sufficiently large so that the capacitance may be printed or stamped directly on the unit. In some cases, additional information, such as the dc working voltage, toler-



Capacitors may be marked as shown here.

ance, and temperature coefficient may also be included. The drawing shows a capacitor having a capacitance of 6,200 pf, a negative temperature coeffifficient of 500 ppm (parts per million per degree centigrade). The tolerance is ±20 percent and the unit has a dc working voltage of 1,000.

Electrolytic capacitors are marked showing the rated capacitance in microfarads, the rated dc working voltage and terminal identification.

Color code for power transformers

Table 48 supplies the color code for power transformers. A bare wire (if used) represents the connection to the Faraday shield (electrostatic screen) between the primary and secondary windings. This wire should be grounded.

Table 48 — Color Code for Power Transformers

	Secondary		
Primary	*Rectifier*	*Filament Windings*	*Color*
Primary (no taps)	—	—	Black
Primary (tapped);			
Common	—	—	Black
Tap No. 1	—	—	Black-yellow
Tap No. 2	—	—	Black-orange
Finish	—	—	Black-red
—	Plate	—	Red
	center tap		Red-yellow
—	Filament	—	Yellow
	center tap		Yellow-blue
		Filament No. 1	Green
—	—	Center tap	Green-yellow
		Filament No. 2	Brown
		Center tap	Brown-yellow
—	—		
		Filament No. 3	Slate
		Center tap	Slate-yellow

Color code for audio interstage and output transformers

Table 49 supplies the coding used for audio interstage and output transformers. In an output transformer, the black lead is the start of ance, and temperature coefficient may also be included. The drawing and a yellow lead in the secondary indicate the start of the windings.

Table 49 —
Color Code for Audio Interstage and Output Transformers

Terminals		*Color*	
Primary	*Secondary*	*Single*	*Push-pull*
Plate	—	Blue	Blue
B-plus	—	Red	Red (tap)
Plate	—	—	Blue or brown
—	Grid (or hot side of moving coil)	Green	Green
—	Return (or ground side of moving coil)	Black	Black
—	Grid	—	Green or yellow

Color code for i.f. transformers

The color code for i.f. transformers is similar to that used for audio transformers. The i.f. color code is given in Table 50.

Table 50 — Color Code for I.F. Transformers

Terminals		Color
Primary	*Secondary*	
Plate		Blue
B-plus		Red
	Grid or diode	Green
	Center tap	Green-black
	Grid or diode return, avc, or ground	Black

Color code for speaker voice coils

Green — finish
Black — start

Mathematics tables

Miscellaneous mathematics tables will be found, beginning on this page and continuing to page 157.

Table 51 — Powers of Two

2^n	n	2^{-n}
1	0	1.0
2	1	0.5
4	2	0.25
8	3	0.125
16	4	0.062 5
32	5	0.031 25
64	6	0.015 625
128	7	0.007 812 5
256	8	0.003 906 25
512	9	0.001 953 125
1 024	10	0.000 976 562 5
2 048	11	0.000 488 281 25
4 096	12	0.000 244 140 625
8 192	13	0.000 122 070 312 5
16 384	14	0.000 061 035 156 25
32 768	15	0.000 030 517 578 125
65 536	16	0.000 015 258 789 062 5
131 072	17	0.000 007 629 394 531 25
262 144	18	0.000 003 814 697 265 625
524 288	19	0.000 001 907 348 632 812 5
1 048 576	20	0.000 000 953 674 316 406 25
2 097 152	21	0.000 000 476 837 158 203 125
4 194 304	22	0.000 000 238 418 579 101 562 5
8 388 608	23	0.000 000 119 209 289 550 781 25
16 777 216	24	0.000 000 059 604 644 775 390 625
33 554 432	25	0.000 000 029 802 322 387 695 312 5
67 108 864	26	0.000 000 014 901 161 193 847 656 25
134 217 728	27	0.000 000 007 450 580 596 923 828 125
268 435 456	28	0.000 000 003 725 290 298 461 914 062 5
536 870 912	29	0.000 000 001 862 645 149 230 957 031 25
1 073 741 824	30	0.000 000 000 931 322 574 615 478 515 625
2 147 483 648	31	0.000 000 000 465 661 287 307 739 257 812 5
4 294 967 296	32	0.000 000 000 232 830 643 653 869 628 906 25
8 589 934 592	33	0.000 000 000 116 415 321 826 934 814 453 125
17 179 869 184	34	0.000 000 000 058 207 660 913 467 407 226 562 5
34 359 738 368	35	0.000 000 000 029 103 830 456 733 703 613 281 25
68 719 476 736	36	0.000 000 000 014 551 915 228 366 851 806 640 625
137 438 953 472	37	0.000 000 000 007 275 957 614 183 425 903 320 312 5
274 877 906 944	38	0.000 000 000 003 637 978 807 091 712 951 660 156 25
549 755 813 888	39	0.000 000 000 001 818 989 403 545 856 475 830 078 125
1 099 511 627 776	40	0.000 000 000 000 909 494 701 772 928 237 915 039 062 5
2 199 023 255 552	41	0.000 000 000 000 454 747 350 886 464 118 957 519 531 25
4 398 046 511 104	42	0.000 000 000 000 227 373 675 443 232 059 478 759 765 625
8 796 093 022 208	43	0.000 000 000 000 113 686 837 721 616 029 739 379 882 812
17 592 186 044 416	44	0.000 000 000 000 056 843 418 860 808 014 869 689 941 406
35 184 372 088 832	45	0.000 000 000 000 028 421 709 430 404 007 434 844 970 703
70 368 744 177 664	46	0.000 000 000 000 014 210 854 715 202 003 717 422 485 351
140 737 488 355 328	47	0.000 000 000 000 007 105 427 357 601 001 858 711 242 675
281 474 976 710 656	48	0.000 000 000 000 003 552 713 678 800 500 929 355 621 337
562 949 953 421 312	49	0.000 000 000 000 001 776 356 839 400 250 464 677 810 668
1 125 899 906 842 624	50	0.000 000 000 000 000 888 178 419 700 125 232 338 905 334
2 251 799 813 685 248	51	0.000 000 000 000 000 444 089 209 850 062 616 169 452 667
4 503 599 627 370 496	52	0.000 000 000 000 000 222 044 604 925 031 308 084 726 333
9 007 199 254 740 992	53	0.000 000 000 000 000 111 022 302 462 515 654 042 363 166
18 014 398 509 481 984	54	0.000 000 000 000 000 055 511 151 231 257 827 021 181 583
36 028 797 018 963 968	55	0.000 000 000 000 000 027 755 575 615 628 913 510 590 791
72 057 594 037 927 936	56	0.000 000 000 000 000 013 877 787 807 814 456 755 295 395
144 115 188 075 855 872	57	0.000 000 000 000 000 006 938 893 903 907 228 377 647 697
288 230 376 151 711 744	58	0.000 000 000 000 000 003 469 446 951 953 614 188 823 848
576 460 752 303 423 488	59	0.000 000 000 000 000 001 734 723 475 976 807 094 411 924
1 152 921 504 606 846 976	60	0.000 000 000 000 000 000 867 361 737 988 403 547 205 962

Table 52 — Powers of Numbers

n	n^4	n^5	n^6	n^7	n^8
1	1	1	1	1	1
2	16	32	64	128	256
3	81	243	729	2187	6561
4	256	1024	4096	16384	65536
5	625	3125	15625	78125	390625
6	1296	7776	46656	279936	1679616
7	2401	16807	117649	823543	5764801
8	4096	32768	262144	2097152	16777216
9	6561	59049	531441	4782969	43046721
					$\times 10^8$
10	10000	100000	1000000	10000000	1.000000
11	14641	161051	1771561	19487171	2.143589
12	20736	248832	2985984	35831808	4.299817
13	28561	371293	4826809	62748517	8.157307
14	38416	537824	7529536	105413504	14.757891
15	50625	759375	11390625	170859375	25.628906
16	65536	1048576	16777216	268435456	42.949673
17	83521	1419857	24137569	410338673	69.757574
18	104976	1889568	34012224	612220032	110.199606
19	130321	2476099	47045881	893871739	169.835630
				$\times 10^9$	$\times 10^{10}$
20	160000	3200000	64000000	1.280000	2.560000
21	194481	4084101	85766121	1.801089	3.782286
22	234256	5153632	113379904	2.494358	5.487587
23	279841	6436343	148035889	3.404825	7.831099
24	331776	7962624	191102976	4.586471	11.007531
25	390625	9765625	244140625	6.103516	15.258789
26	456976	11881376	308915776	8.031810	20.882706
27	531441	14348907	387420489	10.460353	28.242954
28	614656	17210368	481890304	13.492929	37.780200
29	707281	20511149	594823321	17.249876	50.024641
			$\times 10^8$	$\times 10^{10}$	$\times 10^{11}$
30	810000	24300000	7.290000	2.187000	6.561000
31	923521	28629151	8.875037	2.751261	8.528910
32	1048576	33554432	10.737418	3.435974	10.995116
33	1185921	39135393	12.914680	4.261844	14.064086
34	1336336	45435424	15.448044	5.252335	17.857939

Table 52 — Powers of Numbers

n	n^4	n^5	n^6	n^7	n^8
35	1500625	52521875	18.382656	6.433930	22.518754
36	1679616	60466176	21.767823	7.836416	28.211099
37	1874161	69343957	25.657264	9.493188	35.124795
38	2085136	79235168	30.109364	11.441558	43.477921
39	2313441	90224199	35.187438	13.723101	53.520093
			$\times 10^9$	$\times 10^{10}$	$\times 10^{12}$
40	2560000	102400000	4.096000	16.384000	6.553600
41	2825761	115856201	4.750104	19.475427	7.984925
42	3111696	130691232	5.489032	23.053933	9.682652
43	3418801	147008443	6.321363	27.181861	11.688200
44	3748096	164916224	7.256314	31.927781	14.048224
45	4100625	184528125	8.303766	37.366945	16.815125
46	4477456	205962976	9.474297	43.581766	20.047612
47	4879681	229345007	10.779215	50.662312	23.811287
48	5308416	254803968	12.230590	58.706834	28.179280
49	5764801	282475249	13.841287	67.822307	33.232931
			$\times 10^9$	$\times 10^{11}$	$\times 10^{13}$
50	6250000	312500000	15.625000	7.812500	3.906250
51	6765201	345025251	17.596288	8.974107	4.576794
52	7311616	380204032	19.770610	10.280717	5.345973
53	7890481	418195493	22.164361	11.747111	6.225969
54	8503056	459165024	24.794911	13.389252	7.230196
55	9150625	503284375	27.680641	15.224352	8.373394
56	9834496	550731776	30.840979	17.270948	9.671731
57	10556001	601692057	34.296447	19.548975	11.142916
58	11316496	656356768	38.068693	22.079842	12.806308
59	12117361	714924299	42.180534	24.886515	14.683044
		$\times 10^8$	$\times 10^{10}$	$\times 10^{11}$	$\times 10^{13}$
60	12960000	7.776000	4.665600	27.993600	16.796160
61	13845841	8.445963	5.152037	31.427428	19.170731
62	14776336	9.161328	5.680024	35.216146	21.834011
63	15752961	9.924365	6.252350	39.389806	24.815578
64	16777216	10.737418	6.871948	43.980465	28.147498
65	17850625	11.602906	7.541889	49.022279	31.864481
66	18974736	12.523326	8.265395	54.551607	36.004061
67	20151121	13.501251	9.045838	60.607116	40.606768

Table 52 — Powers of Numbers

n	n^4	n^5	n^6	n^7	n^8
68	21381376	14.539336	9.886748	67.229888	45.716324
69	22667121	15.640313	10.791816	74.463533	51.379837
		$\times 10^8$	$\times 10^{10}$	$\times 10^{12}$	$\times 10^{14}$
70	24010000	16.807000	11.764900	8.235430	5.764801
71	25411681	18.042294	12.810028	9.095120	6.457535
72	26873856	19.349176	13.931407	10.030613	7.222041
73	28398241	20.730716	15.133423	11.047399	8.064601
74	29986576	22.190066	16.420649	12.151280	8.991947
75	31640625	23.730469	17.797852	13.348389	10.011292
76	33362176	25.355254	19.269993	14.645195	11.130348
77	35153041	27.067842	20.842238	16.048523	12.357363
78	37015056	28.871744	22.519960	17.565569	13.701144
79	38950081	30.770564	24.308746	19.203909	15.171088
		$\times 10^8$	$\times 10^{10}$	$\times 10^{12}$	$\times 10^{14}$
80	40960000	32.768000	26.214400	20.971520	16.777216
81	43046721	34.867844	28.242954	22.876792	18.530202
82	45212176	37.073984	30.400667	24.928547	20.441409
83	47458321	39.390406	32.694037	27.136051	22.522922
84	49787136	41.821194	35.129803	29.509035	24.787589
85	52200625	44.370531	37.714952	32.057709	27.249053
86	54700816	47.042702	40.456724	34.792782	29.921793
87	57289761	49.842092	43.362620	37.725479	32.821167
88	59969536	52.773192	46.440409	40.867560	35.963452
89	62742241	55.840594	49.698129	44.231335	39.365888
		$\times 10^9$	$\times 10^{11}$	$\times 10^{13}$	$\times 10^{15}$
90	65610000	5.904900	5.314410	4.782969	4.304672
91	68574961	6.240321	5.678693	5.167610	4.702525
92	71639296	6.590815	6.063550	5.578466	5.132189
93	74805201	6.956884	6.469902	6.017009	5.595818
94	78074896	7.339040	6.898698	6.484776	6.095689
95	81450625	7.737809	7.350919	6.983373	6.634204
96	84934656	8.153727	7.827578	7.514475	7.213896
97	88529281	8.587340	8.329720	8.079828	7.837434
98	92236816	9.039208	8.858424	8.681255	8.507630
99	96059601	9.509900	9.414801	9.320653	9.227447
100	100000000	10.000000	10.000000	10.000000	10.000000

Table 53 — Cube Roots of Numbers

n	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$
1	1.000000	2.154435	4.641589
2	1.259921	2.714418	5.848035
3	1.442250	3.107233	6.694330
4	1.587401	3.419952	7.368063
5	1.709976	3.684031	7.937005
6	1.817121	3.914868	8.434327
7	1.912931	4.121285	8.879040
8	2.000000	4.308869	9.283178
9	2.080084	4.481405	9.654894
10	2.154435	4.641589	10.00000
11	2.223980	4.791420	10.32280
12	2.289428	4.932424	10.62659
13	2.351335	5.065797	10.91393
14	2.410142	5.192494	11.18689
15	2.466212	5.313293	11.44714
16	2.519842	5.428835	11.69607
17	2.571282	5.539658	11.93483
18	2.620741	5.646216	12.16440
19	2.668402	5.748897	12.38562
20	2.714418	5.848035	12.59921
21	2.758924	5.943922	12.80579
22	2.802039	6.036811	13.00591
23	2.843867	6.126926	13.20006
24	2.884499	6.214465	13.38866
25	2.924018	6.299605	13.57209
26	2.962496	6.382504	13.75069
27	3.000000	6.463304	13.92477
28	3.036589	6.542133	14.09460
29	3.072317	6.619106	14.26043
30	3.107233	6.694330	14.42250
31	3.141381	6.767899	14.58100
32	3.174802	6.839904	14.73613
33	3.207534	6.910423	14.88806
34	3.239612	6.979532	15.03695
35	3.271066	7.047299	15.18294

Table 53 — Cube Roots of Numbers

n	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$
36	3.301927	7.113787	15.32619
37	3.332222	7.179054	15.46680
38	3.361975	7.243156	15.60491
39	3.391211	7.306144	15.74061
40	3.419952	7.368063	15.87401
41	3.448217	7.428959	16.00521
42	3.476027	7.488872	16.13429
43	3.503398	7.547842	16.26133
44	3.530348	7.605905	16.38643
45	3.556893	7.663094	16.50964
46	3.583048	7.719443	16.63103
47	3.608826	7.774980	16.75069
48	3.634241	7.829735	16.86865
49	3.659306	7.883735	16.98499
50	3.684031	7.937005	17.09976
51	3.708430	7.989570	17.21301
52	3.732511	8.041452	17.32478
53	3.756286	8.092672	17.43513
54	3.779763	8.143253	17.54411
55	3.802952	8.193213	17.65174
56	3.825862	8.242571	17.75808
57	3.848501	8.291344	17.86316
58	3.870877	8.339551	17.96702
59	3.892996	8.387207	18.06969
60	3.914868	8.434327	18.17121
61	3.936497	8.480926	18.27160
62	3.957892	8.527019	18.37091
63	3.979057	8.572619	18.46915
64	4.000000	8.617739	18.56636
65	4.020726	8.662391	18.66256
66	4.041240	8.706588	18.75777
67	4.061548	8.750340	18.85204
68	4.081655	8.793659	18.94536
69	4.101566	8.836556	19.03778
70	4.121285	8.879040	19.12931

Table 53 — Cube Roots of Numbers

n	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$
71	4.140818	8.921121	19.21997
72	4.160168	8.962809	19.30979
73	4.179339	9.004113	19.39877
74	4.198336	9.045042	19.48695
75	4.217163	9.085603	19.57434
76	4.235824	9.125805	19.66095
77	4.254321	9.165656	19.74681
78	4.272659	9.205164	19.83192
79	4.290840	9.244335	19.91632
80	4.308869	9.283178	20.00000
81	4.326749	9.321698	20.08299
82	4.344481	9.359902	20.16530
83	4.362071	9.397796	20.24694
84	4.379519	9.435388	20.32793
85	4.396830	9.472682	20.40828
86	4.414005	9.509685	20.48800
87	4.431048	9.546403	20.56710
88	4.447960	9.582840	20.64560
89	4.464745	9.619002	20.72351
90	4.481405	9.654894	20.80084
91	4.497941	9.690521	20.87759
92	4.514357	9.725888	20.95379
93	4.530655	9.761000	21.02944
94	4.546836	9.795861	21.10454
95	4.562903	9.830476	21.17912
96	4.578857	9.864848	21.25317
97	4.594701	9.898983	21.32671
98	4.610436	9.932884	21.39975
99	4.626065	9.966555	21.47229
100	4.641589	10.00000	21.54435

Table 54 — Numbers and Reciprocals

n	1/*n*	*n*	1/*n*	*n*	1/*n*
0.1	10.0000	28	.0357	65	.0154
0.2	5.0000	29	.0345	66	.0152
0.3	3.3333	30	.0333	67	.0149
0.4	2.5000	31	.0323	68	.0147
0.5	2.0000	32	.0312	69	.0145
0.6	1.6666	33	.0303	70	.0143
0.7	1.4286	34	.0294	71	.0141
0.8	1.2500	35	.0286	72	.0139
0.9	1.1111	36	.0278	73	.0137
		37	.0270	74	.0135
1	1.0000	38	.0263	75	.0133
2	.5000	39	.0256	76	.0132
3	.3333	40	.0250	77	.0130
4	.2500	41	.0244	78	.0128
5	.2000	42	.0238	79	.0127
6	.1667	43	.0233	80	.0125
7	.1429	44	.0227	81	.0123
8	.1250	45	.0222	82	.0122
9	.1111	46	.0217	83	.0120
10	.1000	47	.0213	84	.0119
11	.0909	48	.0208	85	.0118
12	.0833	49	.0204	86	.0116
13	.0769	50	.0200	87	.0115
14	.0714	51	.0196	88	.0114
15	.0667	52	.0192	89	.0112
16	.0625	53	.0189	90	.0111
17	.0588	54	.0185	91	.0110
18	.0556	55	.0182	92	.0109
19	.0526	56	.0179	93	.0108
20	.0500	57	.0175	94	.0106
21	.0476	58	.0172	95	.0105
22	.0455	59	.0169	96	.0104
23	.0435	60	.0167	97	.0103
24	.0417	61	.0164	98	.0102
25	.0400	62	.0161	99	.0101
26	.0385	63	.0159	100	.0100
27	.0370	64	.0156		

Table 55 — Decimal Equivalents of Common Fractions of an Inch

Frac-tions	*64ths*	*32nds*	*16ths*	*8ths*	*4ths*	*Decimal Equivalents*
1/64	1	—	—	—	—	.015625
1/32	2	1	—	—	—	.031250
3/64	3	—	—	—	—	.046875
1/16	4	2	1	—	—	.062500
5/64	5	—	—	—	—	.078125
3/32	6	3	—	—	—	.093750
7/64	7	—	—	—	—	.109375
1/8	8	4	2	1	—	.125000
9/64	9	—	—	—	—	.140625
5/32	10	5	—	—	—	.156250
11/64	11	—	—	—	—	.171875
3/16	12	6	3	—	—	.187500
13/64	13	—	—	—	—	.203125
7/32	14	7	—	—	—	.218750
15/64	15	—	—	—	—	.234375
1/4	16	8	4	2	1	.250000
17/64	11	—	—	—	—	.265625
9/32	18	9	—	—	—	.281250
19/64	19	—	—	—	—	.296875
5/16	20	10	5	—	—	.312500
21/64	21	—	—	—	—	.328125
11/32	22	11	—	—	—	.343750
23/64	23	—	—	—	—	.359375
3/8	24	12	6	3	—	.375000
25/64	25	—	—	—	—	.390625
13/32	26	13	—	—	—	.406250
27/64	27	—	—	—	—	.421875
7/16	28	14	7	—	—	.437500
29/64	29	—	—	—	—	.453125
15/32	30	15	—	—	—	.468750
31/64	31	—	—	—	—	.484375
1/2	32	16	8	4	2	.500000

Table 55 — Decimal Equivalents of Common Fractions of an Inch

Fractions	*64ths*	*32nds*	*16ths*	*8ths*	*4ths*	*Decimal Equivalents*
33/64	33	—	—	—	—	.515625
17/32	34	17	—	—	—	.531250
35/64	35	—	—	—	—	.546875
9/16	36	18	9	—	—	.562500
37/64	37	—	—	—	—	.578125
19/32	38	19	—	—	—	.593750
39/64	39	—	—	—	—	.609375
5/8	40	20	10	5	—	.625000
41/64	41	—	—	—	—	.640625
21/32	42	21	—	—	—	.656250
43/64	43	—	—	—	—	.671875
11/16	44	22	11	—	—	.687500
45/64	45	—	—	—	—	.703125
23/32	46	23	—	—	—	.718750
47/64	47	—	—	—	—	.734375
3/4	48	24	12	6	3	.750000
49/64	49	—	—	—	—	.765625
25/32	50	25	—	—	—	.781250
51/64	51	—	—	—	—	.796875
13/16	52	26	13	—	—	.812500
53/64	53	—	—	—	—	.828125
27/32	54	27	—	—	—	.843750
55/64	55	—	—	—	—	.859375
7/8	56	28	14	7	—	.875000
57/64	57	—	—	—	—	.890625
29/32	58	29	—	—	—	.906250
59/64	59	—	—	—	—	.921875
15/16	60	30	15	—	—	.937500
61/64	61	—	—	—	—	.953125
31/32	62	31	—	—	—	.968750
63/64	63	—	—	—	—	.984375
1 inch	64	32	16	8	4	1.000000

Table 56 — Mathematical Symbols

Symbol	*Name or Meaning*	*Description*
0, 1, 2, 3, 4, etc.	Numbers, numerals, whole numbers	Cardinal (Arabic) numbers used in mathematics. Arithmetic numbers.
No.; no.; #	Abbreviation	Symbol that may precede a number.
i; ii; iii; iv; v I; II; III; IV; V	Numbers	Cardinal (Roman) numbers. Have limited use — introductory pages of books; watches; building cornerstones, etc.
2-1/2; 3-1/8; 4-1/9	Numbers	Mixed number, consisting of a whole number and a proper fraction.
1/2; 3/4; 4/7	Numbers	Proper fraction. Numerator is always smaller in value than the denominator.
5/2; 4/3; 9/5	Numbers	Improper fraction. Numerator is always larger in value than the denominator.
$+$	Plus sign	Positive; plus; addition. May be used to indicate direction.
$-$	Minus sign	Negative; minus; subtraction. May be used to indicate direction.
$\pm$	Plus-minus	Positive or negative; plus or minus; addition or subtraction.
$\mp$	Minus-plus	Negative or positive; minus or plus; subtraction or addition.
a; x; y; z; etc.	Literal numbers	Letters used as a symbol for a number.
25/100; 4/10; 6589/1000	Numbers	Decimal fractions having 10, 100, 1000, etc. in the denominator.

Table 56 — Mathematical Symbols

Symbol	*Name or Meaning*	*Description*
1.657; 0.354 0.25	Decimal point	Point used in decimal fractions when denominator is omitted. The number to the right of the decimal point is the decimal fraction. In some countries a comma is used in place of the decimal point. In the U.S. the decimal point is put at the bottom; in England at the center or higher.
∞	Infinity	All indefinitely great number or amount.
$\times$	Multiply by	Multiplication. A form of repeated addition.
$x \cdot y$	Dot between letters means multiplication	x is multiplied by y.
(x) (y)	Adjacent parentheses means multiplication	x is multiplied by y.
$x \div y$	Straight line with dot above and below means division	x is divided by y.
x/y	Slant line indicates division	x is divided by y. Also, ratio of x to y.
$\frac{x}{y}$	Horizontal line means division	x is divided by y. Also, ratio of x to y.
x : y	Dots indicate division or ratio	x is divided by y; the ratio of x to y.
= or : :	Equals signs	Signs representing equality between two quantities; is equal to.
$\equiv$	Identity sign	Sign representing identity between quantities.

Table 56 — Mathematical Symbols

Symbol	*Name or Meaning*	*Description*
$=$	Approximation sign	Quantities separated by this sign are approximately equal. Congruent.
$\neq$	Inequality sign	Quantities separated by this sign are not equal.
$<$	Inequality	Is less than.
$<<$	Inequality	Is much less than.
$>$	Inequality	Is greater than.
$>>$	Inequality	Is much greater than.
$\geqq$	Inequality or equality	Is equal to or is greater than.
$\leqq$	Inequality or equality	Is equal to or is less than.
$\therefore$	Therefore	Symbol used in geometry and logic.
$\doteq$ or $\rightarrow$ or lim	Approaches as a limit	Variable approaches a constant, but never reaches it.
$\perp$	Perpendicular. Normal	Lines which form right angles.
$\parallel$	Parallel	Lines which are parallel to each other.
$\measuredangle$	Angle. Also positive angle	The angle formed by two lines.
$\measuredangle$s	Angles	Two or more angles.
$\ulcorner$	Negative angle	An angle whose sign, tangent, cosecant and cotangent are negative.
Δ	Change. Increase or decrease. Increment	Capital Greek letter Delta. A similar symbol is used to represent triangles in trigonometry.
$\sqrt{}$	Square root	Quantity raised to the one-half power.
n$\sqrt{}$	nth root	Quantity raised to the nth power.

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