THE USE OF ARITHMETIC IN RADIO

REFERENCE TEXT 36X

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INTRODUCTION

Anyone who has read magazine articles dealing with Radio—anyone who has studied even the first lesson of a radio course—realizes to what extent a knowledge of mathematics will help him. Take for example Ohm's law. Without a knowledge of simple multiplication and division, we could not put Ohm's law to any practical use. But with this knowledge, Ohm's law becomes the most useful of the fundamental principles of Radio and electricity.

Then when we come to the design of power packs, the design of coils, and the calculation of the resonant frequency of a circuit, etc., we must use formulas that are not always as simple as Ohm's law—and yet if we know our "math" they won't be "Chinese puzzles" to us, but "tools" which we will use in our every-day work.

Short cuts which have been developed are included here, not only to show you how radio calculations are made, but so that you may develop a system of rapid calculation which you can put to practical uses as you progress in your radio studies.

We mentioned Ohm's law as if it were the only use for a knowledge of numbers. The more expert radio technician uses a large variety of radio formulas which are given in another reference text. You will be told how to use formulas, including: what is a formula, uses for radio formulas, expressing formulas graphically, how to solve a practical problem with a formula, how to rearrange a formula, and how to design by means of formulas. Rarely will you have to develop your own formula, a task that you should leave to expert research technicians.

But before you can acquire this remarkable ability you must develop ability to compute. You must review or learn to add, subtract, multiply, divide; learn how to work with fractions and decimals, find roots and powers of numbers. If your work requires lots of arithmetic, you should learn how to use logarithms and the slide rule. This text is devoted to this.

ADDITION

As none of us ever has any trouble in the addition of a few numbers, let us start immediately with a long column of large numbers. Let us say we have a nine section voltage divider and that the individual resistance sections were measured in a very accurate bridge. The first section was found to be 4826 ohms, the second 2958 ohms, and so on. We want to check the resistance of the entire unit.

We set down the figures in a column, then proceed to add them.

```
4826
2958
8277
3936
5729
9127
6344
7413
1662
----
        Check
   52          45
  32            49
 49              32
45                52
-----         -----
50272         50272
```

So that our minds can work with a minimum of exertion as we add up the individual columns, we say only the totals in our mind. We don't say 6 plus 8 are 14, 14 plus 7 are 21, 21 plus 6 are 27, etc.—we merely say 14, 21, 27, 36, etc. We find that the right-hand column totals up to be 52. In school we most likely learned to write down the 2 and carry 5 over to the next column. However, it is best not to carry over the figures from one column to another, but put down the totals for the columns as shown.

To check your results, follow the same procedure but start with the left-hand column as shown.

There are several columns of figures below for you to practice on. Strive for speed and accuracy. Check your results as you go along.

53296	4257	4139
19387	9316	3146
23845	8297	9357
72981	5489	2879
68346	2568	5764
71291	4697	3192
36572	3963	8653

Where a great amount of column addition must be done, the time required to do it can be reduced materially by considering three or four figures of a single column at a time. For example, in the problem just worked out, instead of adding 6 + 8 + 7 + 6, etc., add 14 + 13 + 9 + 11, etc. Column addition may also be often simplified by watching for figures that total up to 10 as you go down the column. That is, if there is a 7 and a 3, a 6 and a 4, an 8 and a 2, etc., even though separated by 1 or 2 numbers, we can immediately add 10 to our total and then add the intermediate numbers. Or if there are several similar numbers, it is often easier to determine the number of times this number appears and multiply it out, later adding the odd numbers together, then adding the two totals for the total of the entire column.

One important thing in connection with the use of addition in Radio—and for that matter, the same is true of subtraction—we can deal only with like terms. By this we mean that we can't add ohms and farads, any more than we can add feet and pounds. Likewise, we can't add amperes and milliamperes directly, we must first convert all quantities to similar terms. Thus to add 100 milliamperes to 1 ampere, we would convert the ampere to 1000 milliamperes and then our total would be 1100 ma.

SUBTRACTION

Very few of us have difficulty in subtracting even the most complicated numbers. However, for the sake of completeness let us work out a problem, and follow through the various steps involved.

```
   7   5210
7,849,630
4,291,375
---------
3,558,255
```

Starting at the extreme right, we see immediately that we can't subtract 5 from 0—we can't take away something from nothing. Therefore, we must borrow 10 from the next number (3), leaving 2. Taking 5 from 10 we get 5. Then moving one place to the left we find we can't subtract 7 from 2 so we borrow again, making the 2, 12. As 7 from 12 is 5 we write this down in the answer. Again moving one place to the left we subtract 3 from 5—not 6—because we have borrowed 1 from 6. $5 - 3 = 2$, which we write down. Then 1 from 9 is 8. The next step requires borrowing again as we can't subtract 9 from 4. We take one from the 8 and subtract 9 from 14 which gives us 5. The next is simple—2 from $7 = 5$ and 4 from $7 = 3$.

Answers to problems of this kind are easily checked—all we have to do is to add the answer to the smaller number and if we have subtracted properly, the total will be the larger number of the problem. Thus:

$$\begin{array}{r} 4,291,375 \\ +3,558,255 \\ \hline 7,849,630 \end{array}$$

MULTIPLICATION IN RADIO

Multiplication is nothing more than a short-cut method of addition. This can be easily seen if we consider a simple problem such as 6 × 9. If we were to add 6 nines together we would get 54, but this would be a rather laborious process.

The development of mathematics was due largely to the search for short-cuts, and the multiplication table was evolved early in the history of mathematics to make unnecessary a great deal of cumbersome addition. We learned the multiplication table early in our school life—and now when we see 6 × 9 we know instantly that 6 nines are 54. Refer to Table 1 which is the familiar multiplication table in a shortened form.

In a problem of multiplication such as 6 × 9, the 6 is the *multiplier* and the 9 is the *multiplicand*. The answer, 54, is the *product*.

Now let us consider a problem in which the multiplicand is a large number. Suppose we want to multiply 9,437 by 7. The proper method of solving the problem is as shown below.

$$\begin{array}{r} {\scriptstyle 3\ \ 24} \\ 9,437 \\ 7 \\ \hline 66,059 \end{array}$$

Stated in words, the operation is as follows: 7 × 7 = 49. Set the 9 down as part of the product and carry over the 4, writing it above the next number to be multiplied. 7 × 3 = 21 and adding the carried 4 we get 25. Set down the 5 in the product and carry the 2. 7 × 4 = 28 and adding the carried 2 we get 30. Set down the 0 and carry 3. 7 × 9 = 63 and adding the carried 3 we get 66 all of which we set down in the product to get the entire product 66,059.

As a point of interest it might be stated here that the number 9,437 is the same as 9000 + 400 + 30 + 7. If we multiplied each of these by 7 and added the products we would get 66,059 as shown by the following:

$$\begin{array}{rr} 7\times 9,000 = & 63,000 \\ 7\times 400 = & 2,800 \\ 7\times 30 = & 210 \\ 7\times 7 = & 49 \\ \hline 7\times 9,437 = & 66,059 \end{array}$$

From this we can see if we multiply the sum of several

	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	4	6	8	10	12	14	16	18	20
3	3	6	9	12	15	18	21	24	27	30
4	4	8	12	16	20	24	28	32	36	40
5	5	10	15	20	25	30	35	40	45	50
6	6	12	18	24	30	36	42	48	54	60
7	7	14	21	28	35	42	49	56	63	70
8	8	16	24	32	40	48	56	64	72	80
9	9	18	27	36	45	54	63	72	81	90
10	10	20	30	40	50	60	70	80	90	100

TABLE No. 1

numbers by a number, the product will be equal to the sum of the products of all the multiplicands and the multiplier.

The same can be said in the case where the multiplicand is the difference between two numbers, as for example, 20 − 8. Suppose we have the problem 4 × (20 − 8). Of course this is equivalent to 4 × 12, the product of which is 48. We would arrive at the same answer if we worked it out this way: (4 × 20) − (4 × 8) in which case we would get 80 − 32 or 48.

Now let us consider a problem in which both multiplier and multiplicand are numbers of several places, as for example, 8,468 × 241. This problem is worked out as follows:

```
    8,468
      241
    8 468
   338 72
 1 693 6
2,040,788
```

From this we can see that we multiply first by 1, then by 4, then by 2, in each case off-setting the product one place to the left, for it must be remembered that although we multiply by 4, what we are really doing is multiplying by 40. In the same way, when we multiply by 2, we are really multiplying by 200. Then the various products are added and we have the solution to the entire problem.

Another multiplication problem, in which both multiplier and multiplicand are four place numbers, is worked out below so that you can fix the process firmly in mind. Follow through each step carefully.

```
     3,947
     5,126
    23 682
    78 94
   394 7
19 735
20,232,322
```

In order to gain speed and accuracy in multiplying, work out the following problems several times.

4,157	9,208	7,546
2,631	6,452	3,158

For the purpose of illustrating the use of multiplication, involving numbers of several places, let us take the formula for capacity in a resonant circuit, either series or parallel resonance, $C = \frac{10}{394 f^2 L}$ where C is the capacity in farads, f is the frequency in cycles per second and L is the inductance in henries. Let us forget for the time being the fact that we have to divide $394f^2L$ into 10 and deal only with the lower term. Later when we study division we shall see how a large number is divided into a smaller one or into some multiple of 1.

Now let us say that the frequency is 120 cycles and the inductance is 30 henries. Then instead of $394f^2L$ we would have:

$$394 \times 120 \times 120 \times 30$$

You notice that f^2, which is read "f squared," means that 120 (in this case) must be multiplied by itself. In working out

the problem it will be easiest to multiply out all the simple terms first—as follows:

```
        120
       ×120
      2 400
     12 0
     14 400
        ×30
    432 000
       ×394
  1 728 000
 38 880 00
129 600 0
170,208,000
```

If this final product is divided into 10 we find that C is approximately .00000006 farads.* But we are not interested in the particular value of C in this case, all we wanted to do was to get the value of $394f^2L$ which involves nothing but multiplication.

Before we leave the subject of multiplication of whole numbers there are two points you should memorize. First: When either the multiplier or the multiplicand is zero, the product will be zero. Thus 100×0 or $0 \times 100 = 0$. Second, when either term is 1, the product will be equal to the other term. Thus 1×150 or $150 \times 1 = 150$. These points are emphasized here because, while to many people they are obvious, it often happens that we become confused momentarily when confronted with them in our practical work.

DECIMALS IN ADDITION, SUBTRACTION AND MULTIPLICATION

In practically all radio work involving the use of arithmetic, fractions are converted to decimals for purposes of calculation. For example, we have .0005 mfd. condensers. No one would ever write this $\frac{5}{10,000}$ mfd. It is true we have 1/2 megohm resistors, but even here, when calculations are involved, we convert the 1/2 megohm to .5 megohm or 500,000 ohms.

The decimal system is nothing more or less than a means of expressing numbers less than 1 in terms of tenths.

Simple decimals of this sort will not be difficult for us, as we use them every day in handling money. When we say 50 cents meaning a half dollar, we are really saying 50/100th or

* To find the value in microfarads move the decimal point six places to the right (multiply by 1,000,000). This gives .06 microfarad.

5/10th of a dollar. A quarter is 25 cents, or 25/100th of a dollar; 75 cents is three-quarters of a dollar or 75/100th of a dollar. We write .50, .25, and .75 using the decimal point to show that what follows is really less than 1.

In Radio we deal with decimals to many places, such as .0008, .0025, etc. The table below will show you how these are to be read and includes the fractional equivalents.

.1	=1/10	=one-tenth.
.01	=1/100	=one-hundredth.
.001	=1/1000	=one-thousandth.
.0001	=1/10,000	=one ten-thousandth.
.00001	=1/100,000	=one hundred-thousandth.
.000001	=1/1,000,000	=one millionth.

As a short cut, when reading decimals of a large number of places such as .0008, instead of reading eight ten-thousandths, we aften read "point 0-0-0 eight," "three zeros eight," or even "triple-0 eight." Sometimes even decimals of one place are read in this way. Thus .5 may be read "point five," or "one-half" instead of "five-tenths."

If you should hear someone say that a certain quantity is "5 zeros three," you will know that he means "three-millionths." If you hear "double 0 two five," you will immediately see in your mind .0025 which you know to be 25 ten-thousandths.

In adding or subtracting decimals, all that is necessary is that the decimal points of the various numbers used be in a line vertically. To illustrate:

$$\begin{array}{r} 1.008 \\ .0005 \\ 126.1 \\ 21.004 \\ \hline 148.1125 \end{array}$$

Of course the decimal point in the result will be directly below the decimal points in the numbers added.

The same is true when we subtract decimals. For example:

$$\begin{array}{r} 298.3760 \\ -19.0422 \\ \hline 279.3338 \end{array}$$

When we multiply decimals, the position of the decimal in the set-up of the problem is unimportant. Suppose we repeat one of the problems worked out in the chapter on multiplication, (8468×241), but let us make it 8.468×24.1. We would multiply this out exactly as though there were no decimals and we would get 2,040,788. Now where would we put our decimal

point? Add up the number of decimal places in both the multiplier and the multiplicand, $3 + 1$, then place the decimal point 4 places to the left in the product and the final result is 204.0788.

DIVISION OF WHOLE NUMBERS

Division is the process of arithmetic which can well be considered as being opposite to multiplication. We use division when we want to find out how many times a certain number will "go into" another number, or in other words, what number we would have to multiply by to get that number.

For example, we all know that $3 \times 9 = 27$. We also know that 3 "goes into 27" 9 times and that 9 "goes into 27" three times.

The sign for division is "÷" or the problem can be set down as a fraction—thus $9 \div 3$ and $\frac{9}{3}$ mean exactly the same thing. In this case the number 9 is called the *dividend*, the number 3 is the *divisor* and the answer is the *quotient*.

A brief reference to Table 1 at this point will do two things —it will refresh your mind on the division of single numbers, and it will show you why division may be considered as being the opposite of multiplication. Now, instead of locating our multiplier and multiplicand on the top and left-side of the Table respectively and reading the product at the point where the two columns intersect, locate the divisor on the left-side column and the dividend in the body of the table, then read the quotient in the top horizontal column.

Whenever the divisor is a number less than 13 it is common practice to use the process known as short division. A practical short division problem is worked out below:

$$\begin{array}{r} 4\,1\,5\,6\,3 \\ 9\overline{)3\;7^{1}4^{5}0^{5}6^{2}7} \end{array}$$

Reviewing the process in words: 9 won't go into 3 so we start by dividing 9 into 37. The closest we can get is 4 times. We set the number 4 down in the quotient. But $4 \times 9 = 36$. Therefore we have 1 left over. Write this above the next number in the dividend. Then 9 goes into 14 once with 5 left over. Set the 1 down in the quotient and write 5 above the next number in the dividend, in this case 0. Now 9 goes into 50 five times with 5 left over, etc. The quotient is 41,563.

Where the divisor is a number larger than 12, the "long division" process is used, as illustrated in the following example in which 31 is our divisor and 969,401 is our dividend.

```
      31271
  31)969401
     93
      39
      31
       84
       62
       220
       217
         31
         31
```

You will notice that the process is essentially the same as for short division, but in this case we set our individual products down for convenience. Notice, too, that in each step we carried down the following number in the dividend.

In both the problems worked out here the answer came out even. But suppose the last number in the dividend in the second example had been something other than 1. Let us say for purposes of illustration that the dividend were 969,409. In the final step, then, we would have had 8 left over. We might say that our quotient in this case were 31271 and 8/31, but the more common procedure is to continue dividing and to get the fraction in decimal form. In the dividend place a decimal point after the 9 and after this write down two zeros. Then our dividend will be 969,409.00. We also place a decimal point in the quotient when we begin to carry down the zeros to the right of the decimal point in the dividend. Worked out in this manner, the problem becomes:

```
      31,271.26
  31)969,409.00
     93
      39
      31
       84
       62
       220
       217
         39
         31
          80
          62
          180
          186
```


Notice that in the first step, when we divide 31 into 96, the quotient 3 is written directly above the 6 in the dividend. Then the decimal point in the quotient is placed directly above the decimal point in the dividend.

Where the dividend contains a decimal the procedure is the same as that just illustrated. In the process of dividing, place a decimal in the quotient at the point where the first number to the right of the decimal in the dividend is carried down. If the quotient is set down carefully, this decimal will be directly above the decimal in the dividend.

Where the divisor contains a decimal, the simplest procedure is to make a whole number of it and move the decimal in the dividend the same number of places to the right as it must be moved in the divisor to make it a whole number. For example, let us say we have the problem $974.63 \div 1.3$. We simplify this by making it $9746.3 \div 13$. A slightly more difficult problem would be $1.41 \div .0025$. To make of the divisor a whole number, we have to move the decimal four places to the right and our problem becomes $14100 \div 25$ or $\frac{14100}{25}$

On the other hand, suppose we have to divide a whole number into a decimal, as for example: $.0007 \div 45$ or $\frac{.0007}{45}$ We would work this out as follows:

```
       .0000155
  45).0007000
         45
         250
         225
          250
          225
```

Notice that we set down in the quotient the three zeros in the dividend. Then because 45 won't go into 7, we set down another zero. Now 45 goes into 70 once and we set down the number 1 in the quotient. 45 from 70 leaves 25. Bring down a zero from the dividend and divide 45 into 250. It goes 5 times with 25 left over. Bring down another zero and divide 45 into 250. It goes 5 times and we set the 5 down in the quotient. We could continue adding zeros to the dividend all we wanted to, but for most purposes we are satisfied with three significant numbers in the quotient. In this case our quotient is 155 ten-millionths.

Now you will be able to see how we obtained .00000006 farads when we divided 170,208,000 into 10 in a previous chapter. We set the problem down as below, adding the required number of zeros to the dividend.

```
                00.000000058
170,208,000)10.000000000
                 8 51040000
                 1 489600000
                 1 361664000
```

You will notice we had to add 9 zeros to the dividend. Therefore, there will be nine places in the quotient and the answer would be read 58 thousand-millionths. But the answer is in farads so we convert it to microfarads by multiplying by 1 million and we get .058 or .06 mfd.

In radio work we frequently have to divide a whole number into 1 in order to obtain the reciprocal. The procedure is exactly the same as outlined above. Suppose we want to find the conductance $\frac{1}{R}$ when R is 2500 ohms. We proceed as follows:

```
      0.0004
2500)1.0000
      1 0000
```

Notice that the quotient has as many places as the dividend. The conductance in this case would be 4 ten-thousandths of a ohm.

To check the correctness of a quotient, multiply it by the divisor. The result should be the same as the dividend.

SHORT CUTS IN MULTIPLICATION AND DIVISION

Many short cuts have been devised to aid in the rather tedious task of multiplying large numbers. One of the simplest short cuts has to do with the multiplication of numbers containing several zeros.

As an example, 24,000 × 4,000 = 96,000,000. Multiply the numbers together, exclusive of the zeros, and add to the answer as many zeros as appear in both multiplicand and multiplier. In our problem we multiply 24 × 4 = 96. There are three zeros in both terms of our example, therefore, there will be six zeros in the product.

Considerable time is also saved by the proper choice of multiplier. In multiplication it doesn't make any difference which term we use as the multiplier. It is always good policy to make the smaller term the multiplier. For example, we are to multiply 5134 and 2100. With 5,134 as the multiplier our problem would be set up thus:


```
     2 100
     5 134
     8 400
    63 00
   210 0
 10 500
 10,781,400
```

Using 2100 as the multiplier would be much simpler as shown below:

```
   513 4
     2 100
   513 4
10 268
10,781,400
```

In this set-up, we followed our rule about numbers containing zeros, adding two zeros to the product of 5,134 × 21.

A short cut can be used where a number is multiplied by ½ (.5), ¼ (.25), and ¾ (.75).

(A) To multiply by .5—

In order to multiply a number by .5, divide the number by 2. This is self-evident, as .5 is the same as 5/10, which is equal to ½. If the number is 15, we see that 15 × .5 is the same as 15 × ½, which becomes 7.5.

(B) To multiply by .05—

In order to multiply a number by .05, move the decimal point of the number one place to the left and divide by 2. Take the case where 5 per cent of a number is required. Now 5 per cent is 5/100 of a number, which becomes in decimals .05. If the number is 15, move the decimal point of the number one place to the left, which gives 1.5 and divide by 2, obtaining .75.

(C) To multiply by .25—

In order to multiply any number by .25, divide by 4. Thus, if the number 264 is to be multiplied by .25, it is seen that considerable figuring would be necessary to multiply it out. But by dividing by 4, we quickly obtain the answer 66.

We can use this same method whether our multiplier is 2.5, 25, 250, or 25 million, simply by adding to the multiplicand as many zeros as there are whole numbers in the multiplier. Mul-

N	0	1	2	3	4	5	6	7	8	9	P. P. 1. 2. 3. 4. 5
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4. 8.12.17.21
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4. 8.11.15.19
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3. 7.10.14.17
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3. 6.10.13.16
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3. 6. 9.12.15
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3. 6. 8.11.14
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3. 5. 8.11.13
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2. 5. 7.10.12
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2. 5. 7. 9.12
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2. 4. 7. 9.11
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2. 4. 6. 8.11
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2. 4. 6. 8.10
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2. 4. 6. 8.10
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2. 4. 5. 7. 9
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2. 4. 5. 7. 9
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2. 3. 5. 7. 9
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2. 3. 5. 7. 8
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2. 3. 5. 6. 8
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2. 3. 5. 6. 8
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1. 3. 4. 6. 7
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1. 3. 4. 6. 7
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1. 3. 4. 6. 7
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1. 3. 4. 5. 7
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1. 3. 4. 5. 6
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1. 3. 4. 5. 6
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1. 2. 4. 5. 6
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1. 2. 4. 5. 6
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1. 2. 3. 5. 6
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1. 2. 3. 5. 6
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1. 2. 3. 4. 6
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1. 2. 3. 4. 5
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1. 2. 3. 4. 5
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1. 2. 3. 4. 5
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1. 2. 3. 4. 5
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1. 2. 3. 4. 5
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1. 2. 3. 4. 5
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1. 2. 3. 4. 5
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1. 2. 3. 4. 5
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1. 2. 3. 4. 4
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1. 2. 3. 4. 4
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1. 2. 3. 3. 4
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1. 2. 3. 3. 4
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1. 2. 2. 3. 4
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1. 2. 2. 3. 4
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1. 2. 2. 3. 4

N	0	1	2	3	4	5	6	7	8	9	P. P. 1. 2. 3. 4. 5
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1. 2. 2. 3. 4
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1. 2. 2. 3. 4
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1. 2. 2. 3. 4
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1. 1. 2. 3. 4
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1. 1. 2. 3. 4
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1. 1. 2. 3. 4
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1. 1. 2. 3. 4
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1. 1. 2. 3. 3
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1. 1. 2. 3. 3
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1. 1. 2. 3. 3
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1. 1. 2. 3. 3
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1. 1. 2. 3. 3
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1. 1. 2. 3. 3
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1. 1. 2. 3. 3
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1. 1. 2. 3. 3
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1. 1. 2. 2. 3
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1. 1. 2. 2. 3
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1. 1. 2. 2. 3
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1. 1. 2. 2. 3
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1. 1. 2. 2. 3
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1. 1. 2. 2. 3
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1. 1. 2. 2. 3
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1. 1. 2. 2. 3
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1. 1. 2. 2. 3
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1. 1. 2. 2. 3
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1. 1. 2. 2. 3
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1. 1. 2. 2. 3
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1. 1. 2. 2. 3
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1. 1. 2. 2. 3
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1. 1. 2. 2. 3
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1. 1. 2. 2. 3
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1. 1. 2. 2. 3
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0. 1. 1. 2. 2
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0. 1. 1. 2. 2
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0. 1. 1. 2. 2
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0. 1. 1. 2. 2
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0. 1. 1. 2. 2
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0. 1. 1. 2. 2
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0. 1. 1. 2. 2
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0. 1. 1. 2. 2
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0. 1. 1. 2. 2
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0. 1. 1. 2. 2
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0. 1. 1. 2. 2
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0. 1. 1. 2. 2
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0. 1. 1. 2. 2

tiplying by 2.5 we would add one zero and divide by 4. Multiplying by 25 we would add 2 zeros and divide by 4, etc.

(D) To multiply by .75—

In order to multiply any number by .75, divide by 4 and then multiply the result by 3. Take the number 264 to be multiplied by .75. Applying the rule, we have 264 divided by 4 equals 66 and when multiplied by 3 we get 198.

To multiply by 7.5, 75, 750, etc., add zeros to the multiplicand as when multiplying by variations of .25.

(E) To divide any number by 25—

In order to divide any number by 25, move the decimal point two places to the left, and multiply by 4. Taking the number 2640, we move the decimal two places to the left and we have $26.40 \times 4 = 105.6$.

To divide by 250, move the decimal 3 places to the left and multiply by 4. To divide by 2500, move the decimal 4 places, etc.

In the same way, to divide 50, 500, 5000, etc., move the decimal point in the dividend to the left as many places as there are whole numbers in the divisor, then multiply by 2. To divide by .5, multiply by 2 without moving the decimal. To divide by .05, move the decimal one place to the right. If there is no decimal in the dividend, add a zero, then multiply by 2.

LOGARITHMS

In this lesson on arithmetic we are not going to consider the longhand methods of finding the square root, the cube root, etc., or of raising a number to a certain "power," such as squaring it or cubing it. Instead we are going to learn how to use logarithms—the short cut method of multiplying, dividing, extracting roots and raising numbers to the required powers. After all, what we are interested in learning is how practical radio men calculate—and they use logarithms whenever possible as a convenient short cut method.

Let us begin our study of logarithms with a consideration of the simple number 10. If we multiply 10 by itself, which is the same as *squaring* it, we get 100. That is, 10×10 or $10^2 = 100$. In the same way $10 \times 10 \times 10$ or $10^3 = 1000$ and $10 \times 10 \times 10 \times 10$ or $10^4 = 10{,}000$.

In the expressions 10^2, 10^3 and 10^4, the small number to the right is the power, or the *exponent*. And from the figures given it is clear that if we wrote the number 10 with an exponent, it would be 10^1.

Conversely, if we had the number 100, the square root ($\sqrt{100}$) would be 10 for $10 \times 10 = 100$. Likewise the cube root of 1000 ($\sqrt[3]{1000}$) would be 10 and the fourth root of 10,000 ($\sqrt[4]{10{,}000}$) would be 10 for 10^4 or $10 \times 10 \times 10 \times 10 = 10{,}000$.

Of course, all this is very simple, but it is not quite as easy to realize that *any number* can be expressed in terms of 10 raised to a certain power. Take for example, the number 2. This could be expressed as $10^{.301}$ which is to say that if it were possible to multiply the number 10 by itself .301 times, the product would be 2. In this case, the exponent .301 is called the *logarithm* of the *number* 2.

Then let us take another example. The number 44 can be expressed as $10^{1.6435}$. The logarithm of the number 44 is 1.6435. Notice now that the logarithm is divided in two parts—one part to the left of the decimal, the other to the right of the decimal. The part to the left is called the *characteristic* and the part to the right is the *mantissa* of the logarithm (or log).

The characteristic of a log tells us how many whole numbers there are in the *number*. Thus, a characteristic of 1 means that there are two whole numbers in the *number*. If it were 2, there would be 3 whole numbers in the *number*, that is, the *number* would be between 100 and 999. Stated differently, the characteristic is always 1 less than there are whole numbers in the original *number*.

The following table will help to make this clear.

For numbers from:	*Characteristic*
1 to 9	0.
10 to 99	1.
100 to 999	2.
1,000 to 9,999	3.
10,000 to 99,999	4.
100,000 to 999,999	5.

From this we are led naturally to the question of what the characteristic will be if the *number* is less than 1, such as .4321. The rule in this case is that the characteristic will always be 1 more than the number of zeros immediately following the decimal point, *but it will be preceded by a minus sign*. In the example given, the characteristic will be −1 for there is no zero after the decimal and nothing plus one equals 1. Here is another table showing the various characteristics of *numbers* less than 1.

For numbers from:	*Characteristic*
.9 to .1	−1.
.09 to .01	−2.
.009 to .001	−3.
.0009 to .0001	−4.
.00009 to .00001	−5.

Having well in mind the use and meaning of the characteristics of logs, we are now ready to work with mantissae. To obtain the mantissa of any number we shall have to have a log table available such as the short table in the center of this book. You will notice that only mantissae are given.

Let us start with the number 39. We know that the characteristic will be 1. The mantissa we find to be 5911 from our log table. Therefore, the log of 39 is 1.5911. If the number had been 3.9, our log would have been .5911. If .39, it would be −1.5911. If .0039, the log would be −3.5911, etc.

If we have a three-place number such as 599 we first set down the characteristic 2, then in the N column we locate 59. Then we move over to the 9 column and we obtain the mantissa 7774. Our complete log is now 2.7774.

MULTIPLICATION AND DIVISION BY LOG METHOD

Right here we are going to see to what extent long multiplication and division problems can be simplified by the use of logarithms. *To multiply, add the logs of the numbers—to divide, subtract the logs of the numbers.*

Suppose we want to multiply 599 by 39. We have already found the logs, 2.7774 and 1.5911 respectively. Adding 2.7774 and 1.5911 we get 4.3685. Now all we have to do is to convert the log 4.3685 to a number and we will have our product.

We know that our product is going to be between 10,000 and 99,999 because the characteristic is 4. Now we try to locate the mantissa 3685 in the log table. We can't find it directly, but we can locate 3674 and 3692. As 3685 is nearer the latter, let us take that one and our number is 23,400. Notice we have to add 2 zeros because our number must be between 10,000 and 99,999. If we multiplied this out by the long method we would get 23,361.

For most practical work in Radio 23,400 would be close enough, but under some circumstances it might be desired to have four significant terms in the answer.

If we wanted to have our answer correct to four places we

would use the last column (P.P.—proportional parts) of the log table. We would locate the mantissa nearest to 3685, in this case the larger one, 3692. This is larger than 3685 by 7. Now in the last column look up 7. The proportional part for 7 is 4—reading at the top of the column. Subtracting 4 from 2340 we get 2336, and our number is 23,360—with 4 significant terms.

For purposes of additional illustration let us solve the problem 965.43 × 83.97.

The log of 965.43 is 2.9847. Notice that we disregard the last number 3. The log of 965 is 9845. In the last column (P.P.) we locate the next significant figure 4 at the top. Reading down the column, opposite 96, we find the number 2 which we add to the mantissa making it 9847.

The log of 83.97 is 1.9241. First find the mantissa for 840 (because the final number 7 is larger than 5, we work backwards from 84.00). This is 9243. The difference between 8400 and 8397 is 3 which we look up in the last column. The proportional part for 3 is 2 and so we subtract 2 from 9243 and our log is 1.9241.

Now we are ready to add the logs and 2.9847 + 1.9241 = 4.9088. Converting this to a number, we get 81,070. We do this by locating the mantissa nearest to 9088 which is 9090. The number is 81,100. But 9088 is 2 less than 9090. To get the final result we get the number for the proportional part 2, which is 3. Subtracting from the fourth term of 81,100, we get the final answer 81,070.

If we were to work out our problem by arithmetic, we would get as our product, 81,067.1571. However, except where computations involving money are made, four significant figures are sufficient so that our product 81,070 is close enough for all practical purposes.

At this point you are urged to work out a number of multiplication problems, both by arithmetic and by logarithms. After going through the procedure a few times, checking your work as you go along, you will begin to appreciate how easy and convenient it is to use logs.

Division by the use of logarithms is just as simple as multiplication. As an example, let us take a problem we worked out by long division in a previous chapter, i. e., 969,409 ÷ 31. Disregarding the last two figures (09) in the dividend as being insignificant, the log is 5.9865. The log of 31 is 1.4914. Subtracting these we get 4.4951 which is the log of our quotient.

Converting this to a number we get 31,270 which for practical purposes is as good as our other quotient 31,271.26.

A slightly more difficult problem would be to divide .000375 by, let us say, 17. The log of .000375 is —4.5740 and the log of 17 is 1.2304. Our next step is to subtract the logs but the problem (—4.5740) — 1.2304 presents difficulties. To make the first log a plus value so we can subtract from it we make use of a subterfuge. We write the problem down as follows:

$$\begin{array}{r} 6.5740-10 \\ -1.2304 \\ \hline +5.3436-10 \end{array}$$

This, of course, is equivalent to —5.3436. Notice that our subterfuge consisted of replacing the —4 with 6 — 10 which is exactly the same. But we got a plus value which is essential before we can take something away from it. It is obvious that we can't take something away from nothing—and it is just as impossible to take something away from a negative value which is less than nothing.

Converting —5.3436 to a number, we find it is .00002206.

POWERS AND ROOTS

The squaring of large numbers and finding the square roots of large numbers are by no means simple tasks if ordinary methods of arithmetic are used. And when powers and roots other than 2 are involved, the arithmetical procedures are extremely complicated.

Of course you know that 25^2 is another way of writing 25×25. It is to be read "25 squared." Similarly 25^3 means that 25 is to be raised to the 3rd power, and 25^4 means that 25 is to be raised to the 4th power, that is, $25 \times 25 \times 25 \times 25$.

The radical sign $\sqrt{}$ over a number indicates that the square root of that number is to be taken. The sign $\sqrt[3]{}$ means that the cube root is to be taken, and $\sqrt[4]{}$ means that the number is to be reduced to the 4th root.

By the use of logarithms, any problems involving the raising of a number to any power, or the reduction of a number to any root is extremely simple.

To square a number, multiply its log by 2. To cube, multiply its log by 3. To raise a number to the 17th power, multiply its log by 17, etc. To find the square root of a number, divide

its log by 2. To find the cube root, divide the log by 3. To find the 17th root, divide the log by 17, etc.

The practical problems worked out below will serve as illustrations. Study over them carefully—check the logs against the log table—and the processes involved will be very clear to you.

(1) $393^2 = 393 \times 393$

$$\begin{array}{r} \log 393 = 2.5944 \\ 2 \\ \hline 5.1888 \end{array}$$

N = 154500

(2) $\sqrt{53000}$

log 53000 = 4.7243

4.7243 ÷ 2 = 2.3621

N = 230

(3) $25^3 = 25 \times 25 \times 25$

$$\begin{array}{r} \log 25 = 1.3979 \\ 3 \\ \hline 4.1937 \end{array}$$

N = 15620

(4) $\sqrt[3]{15620}$

log 15620 = 4.1937

4.1937 ÷ 3 = 1.3979

N = 25

THE PRINCIPLE OF THE SLIDE RULE

The slide rule is the most commonly used labor saving device for mathematical computations involving multiplication and division. The underlying principle of the slide rule is the logarithm and the operation of a slide rule involves merely the changing of the position of one logarithmic scale with respect to another logarithmic scale.

You are familiar to some extent with logarithmic scales for you have seen characteristic curves of receivers plotted logarithmically. You will have noted too that on a logarithmic scale, the divisions become smaller from 1 to 10. That is, from 1 to 2 is a larger division than from 2 to 3, while the division between 9 and 10 is the smallest of them all.

Two logarithmic scales are shown in Fig. 1. They can be considered as replicas of two logarithmic scales on a typical slide rule. Now, since it is possible to multiply two numbers by adding their logs it is obvious that if we set the slide rule so that the logarithmic scales are placed as shown in Fig. 2, we can multiply any number up to 5 by 2 and obtain the product simply by referring to the multiplicand in the upper scale and reading the product on the lower scale.

If we wanted to multiply numbers larger than 5 by 2 we would place the scales as shown in Fig. 3 and follow the same procedure.

Suppose we wanted to multiply 3 by 2. On the upper scale in Fig. 2 we would locate the number 3 and the product would be indicated directly below it on the lower scale. Likewise if we wanted to multiply 2 × 9 we would place the scales as shown in Fig. 3. Locating the 9 on the top scale we would read 18 on the bottom scale.

Stated very briefly, the process of multiplication with a slide rule is as follows: Set the number 1 of the upper scale over the multiplier on the lower scale, locate the multiplicand on the upper scale and read the product directly on the lower scale, below the multiplicand.

We can move the upper scale either to the right or the left, using the left hand 1 or the right hand 1 (10) as the index, depending on which is the more convenient.

By using the various subdivisions we can multiply larger numbers. Suppose we want to multiply 78 by 23. We move the upper scale to the left until the right-hand 1 is over 23 on the lower scale as shown in Fig. 4. Then locating 78 on the upper scale we read the product on the lower scale and we find it to be 1795. If we multiplied this out by longhand we would get the product as 1794. In practice, 1790 would be close enough as accuracy to three places, that is, to within 2 per cent, is sufficient.

Of course the slide rule does not tell us how many places there are going to be in the product, or if we are dealing with decimals it does not tell us where the decimal should be placed in the product. We must determine the number of places or the position of the decimal by inspection. When multiplying 23 by 78 for example, we can see at a glance that the product will be above 1000 and below 10,000 for 20 × 70 = 1400. In a later chapter we shall learn more about decimal location, etc., by inspection.

Division by means of a slide rule is just as simple as multiplication. The process is essentially one of subtracting. We use the same scales as in multiplication.

In dividing we position the upper scale so that the divisor is directly above the dividend and read the quotient on the lower scale directly under the index 1.

Suppose we want to divide 3 into 6. We place the 3 of the upper scale directly above the 6 of the lower scale. Then under the index 1 we read the quotient on the lower scale which is 2. We would divide 300 into 600 or 3,000,000 into 6,000,000 in exactly the same way. Or we could divide 30 into 6,000,000 in which case we would have to determine the number of zeros in the quotient by inspection.

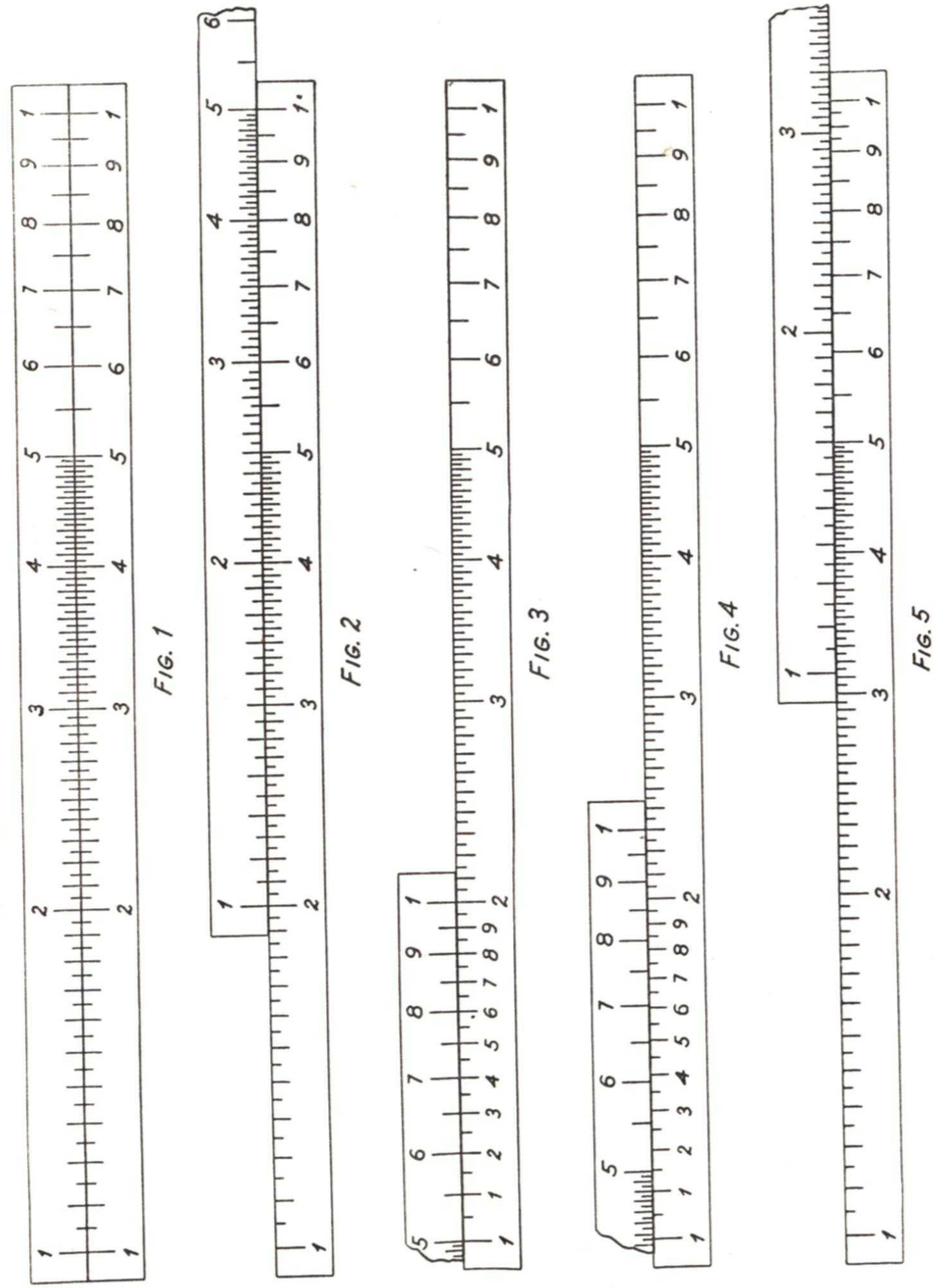

FIG. 1 FIG. 2 FIG. 3 FIG. 4 FIG. 5

Let us take a slightly more difficult problem such as the one we worked out by long division in a previous chapter. The problem is to divide 969,409 by 31. We locate the divisor 31 on the upper scale and move it directly above 969 on the lower scale as in Fig. 5. Notice that we disregard the last three figures as insignificant. We now read the quotient directly below the index 1, on the lower scale, and we find it to be slightly less than 313. By inspection we know that the quotient must be between 10,000 and 100,000, therefore we add two zeros to 313 to get 31,300. If we were dealing with money, of course this would be too inaccurate. There would be too much difference between $31,300 and $31,271.26, but in Radio and for most practical purposes, the answer as given by the slide rule will be close enough.

LOCATION OF DECIMALS BY INSPECTION

When using a slide rule, the only way of finding out how many places there will be in the answer, or where the decimal point belongs, is by inspection. We shall consider briefly inspection in multiplication and division.

Inspection in multiplication. Consider 3856 × 4.414: Inspection will show that the answer will contain five whole figures, for the answer will be a little more than 4 × 3856. Thus, 3856 × 4.414 gives 17,030.

Consider 3856 × 441.4: Think of the number as being multiplied by 4 with the decimal moved two places to the right. Then, the number multiplied by 4 will give five figures, plus two ciphers which will give the answer in 7 places. Thus, 3856 × 441.4 gives 1,703,000.

Consider 3856 × .0004414: Think of the number as being multiplied by 4 with the decimal point moved 4 places to the left. Then the number multiplied by 4 will give five figures but with the decimal moved 4 places to the left. Thus 3856 × .0004414 equals 1.703.

Inspection in division. Consider the fraction .3856/4414: Think of the denominator 4414 as having the decimal after the first figure. Then, move the decimal point in the numerator the same number of places in the same direction. Making the above mental operations we think of the denominator as having the decimal after the first figure, thus 4.414, and then moving the decimal point in the numerator three places in the same direction, we have .0003856/4.414, where we see that 4 will go into

the numerator about .00009. The correct answer is .0000874.

Consider the fraction 38.56/.0004414: We have, by placing the decimal mentally in its proper place 385600/4.414, where we see that 4 will go into the numerator about 90,000 times. The correct answer is 87,400.

SIGNIFICANT FIGURES

In the previous chapters we frequently mentioned significant figures and it was stated several times that a result that was accurate to 3 or 4 places was sufficiently accurate for most practical purposes.

It must not be thought from this that radio engineers and engineers of all other kinds are careless or are willing to sacrifice accuracy for convenience.

The true justification of this simplified method of computation is to be found in the fact that beyond a certain point the numbers represent such small values that they are insignificant. There is a very homely example which will serve to illustrate this nicely—suppose you had $10 and you wanted to divide it into 3 parts. Let us say you wanted first to calculate the value of each part. You would divide 3 into 10 and get $3.33. You could keep on dividing and get 3.333—and an infinite series of 3's if you wanted to but there would be no point to it for any number of 3's you might add to $3.33 would not affect the $3.33.

In this case the significant numbers are limited to those which have their counterpart in dollars and cents, that is, they are limited by the practical consideration of our system of money.

In Radio our limitations are still greater for they are imposed by the accuracy of electrical instruments which are seldom accurate to more than 5 per cent. Suppose we had a 45.7 ohm resistor as measured by a high grade ohmmeter and with a precision ammeter we discover that 3.16 amperes of current were flowing through the resistor. To find the voltage we will multiply 45.7 by 3.16. If we worked this out arithmetically we would get 144.412 volts. But no voltmeter designed to read more than 100 volts would indicate differences of thousandths of volts. In fact, it would take a very good voltmeter to read 144.4 volts. Therefore, the last two figures are insignificant and for practical purposes 144.4 is as correct as 144.412 volts.

Let us take another example—suppose we used a Wheatstone bridge to measure the resistance of a resistor and found it to be 45.72 ohms. Then suppose that the current through the resistor fluctuates but we read an average value of 3.2 amperes. The voltage will be 3.2 × 45.72 or 146.304 volts—if we worked it out the long way. But 146 volts would be just as accurate—first because any voltmeter we might use to check our calculations would not give a reading containing six significant figures and second because the voltmeter reading would not be constant as the current is not constant. The chances are the voltmeter reading would vary between 145 and 147.

A general rule that it is always safe to follow is that if two numbers are multiplied or divided or added, the answer should contain as many significant figures as the least accurate number. In the example just given, 3.2 amperes is rather inaccurate so that even though the value of the resistance is known quite accurately, our result can't be entirely accurate and 3 or 4 significant figures will be as close as we need ever come.

In general radio calculations only three significant figures are considered. Thus in calculating, we would substitute 39600 for 39607; .217 for .21653, etc.

PRACTICAL SLIDE RULE CALCULATION

A typical commercial slide rule is shown in Fig. 6. It is known as the Polyphase (Manheim) Slide Rule and is manufactured by Keuffel & Esser, 127 Fulton Street, New York City.

You will note two upper logarithmic scales, A on the rule and B on the slider; also two lower scales, C on the slider and D on the rule. The glass with a vertical engraved line through the center is known as the runner. A little later we shall see how it is used. Between the B and C scales on the slide there is a "CI" scale, known as the inverted C scale. Below the D scale we find another scale marked K, used with the D scale to find cubes and cube roots. The slider has three scales on the reverse side which may be observed in the actual rule by pulling out the slider. These scales are marked S, L, and T. They are used with the top scales for calculations involving sines, logarithms and tangents.

Suppose we wish to multiply 78 by 23. We shall use the C and D scales. Set 1 on the right-hand* end of the C scale above 78 on the D scale; move the runner so that the cross hair is at 23 on the C scale, the answer is read on the D scale, 1,795.

*If the left-hand 1 of scale C is used, as would appear natural at first, reading under 23 on the D scale would be impossible. By using the right-hand 1 of the C scale, we are in actuality placing a second D scale after the first.

To simplify multiplication the CI scale is used. Again multiply 78 × 23. Set the runner on 78 of the D scale, move the slider until 23 on CI scale is on the engraved line of the runner. Read the answer below 1 on the C scale—either the right or left hand will indicate the answer. It makes little difference whether 78 or 23 is used on the D scale.

Squares and square roots may be found by use of the runner alone. To find the square of a number, locate the number on the D scale with the cross hair and read the answer directly on the A scale. For example, setting the cross hair on 4 of the D scale, we find that the square is 16. Again, the square of 8 is 64. Note that the numbers mentioned here might be 8, 80, 800, etc., and the squares would be 64, 6,400, 640,000.

Note that the A scale is really two log scales exactly alike and we may call the left scale A1 and the right scale A2. In finding the square root of a number, arithmetically, we divide the number into groups of two figures each from the left and right of the decimal point. For example 25′00, 6′72, 97′40, 5. In determining whether the A1 or A2 scale is to be used, we only consider the number in the first group, that is, 25, 6, 97, 5. When there are two figures, use A2—when only one, use A1, thus 25 (A2)—6 (A1)—97 (A2)—5 (A1).

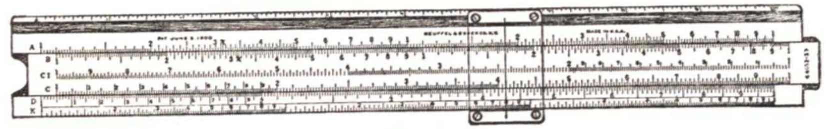

Fig. 6

To find the square root of 25′00, set the cross hair on 25, on the A2 scale, locate the answer 5 on the D scale. The actual answer is 50.

If we wanted to find the square root of a decimal, we would proceed as before, to divide our number into groups of figures from the right of the decimal point, thus .00′36. Rule: If the first group containing digits, after the ciphers, contains one or two such digits, we use A1 or A2, respectively.

Our number contains 2 digits in the group after the zeros and therefore we locate 36 on the A2 scale. The answer 6 is found on the D scale, directly underneath. Our problem was the square root of .0036, therefore the answer is .06.

To find the cube of a number, set the cross hair at the number on D, and read the cube directly on K. The cube of 4 is 64; again the cube of 8 is 512.

Note that the K scale consists of three identical log scales, referred to as K1, K2, K3, reading from left to right. Again we will use a rule to determine which to use when finding cube roots. Rule: For numbers greater than 1 begin at the decimal point and mark off the number into groups of three figures. If the last group contains one, two, or three figures, we use K1, K2, or K3 respectively. To illustrate, let us take the number '216. This number contains 3 figures, so we use K3. Setting the runner and cross hair on 216 of K3, we read 6, directly above it.

If the number is a decimal we group the numbers in threes, beginning from the decimal point and working toward the right, thus, .008'. Rule: If the first group containing digits after the ciphers contains one, two, or three such digits, use K1, K2, or K3. Our number contains one digit, 8, after the ciphers so we use K1, and find the cube root on the D scale is .2.

IF—

If you can dream—and not make dreams your
    master;
  If you can think—and not make thoughts your
    aim;
If you can meet with Triumph and Disaster
  And treat these two impostors just the same; . . .
If you can fill the unforgiving minute
  With sixty seconds' worth of distance run,
Yours is the Earth and everything that's in it,
  And—which is more—you'll be a Man, my son!

* * * *

This poem by Rudyard Kipling has long been an inspiration to me, so I am passing it along to you.

J. E. Smith