NOMORULE:

A Complete Calculator on a Sheet of Paper

Part 1—Use it wherever you would use a slide rule. Keep your results as long as you like! A portable computer on paper for desk or workbench

By JOHN H. FASAL*

YOU'VE PROBABLY HAD IT DRUMMED INTO you by now that a slide rule is a tremendous time and labor saver for anyone who works with numbers. But do you use one? Whether you do or not, you're in a bit of a bind if you work in several places. You can have several slide rules, or you can carry one with you. The first is expensive, the second a nuisance.

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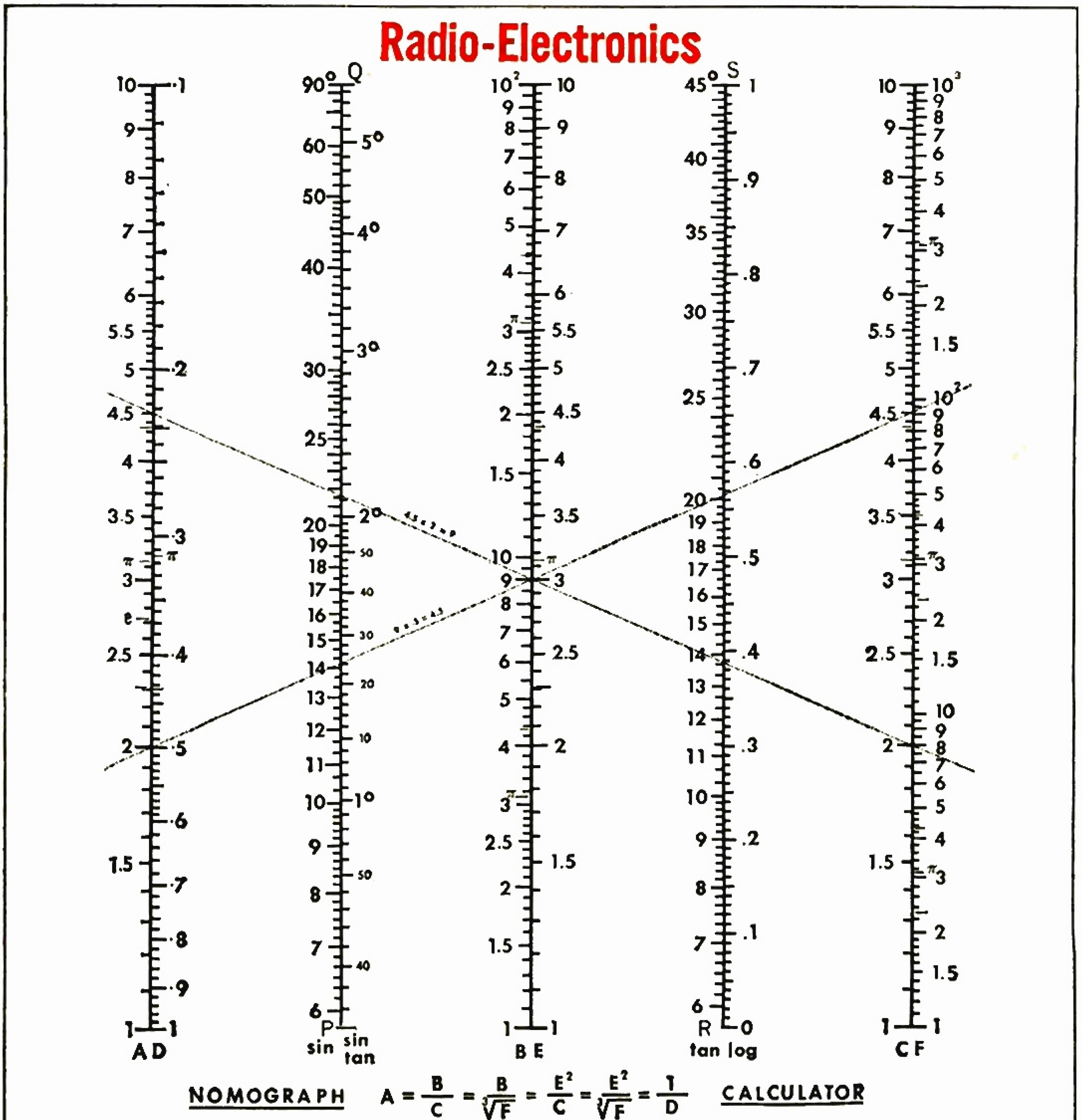

Fig. 1—This is the Nomorule. Simply cut it out, back it with cardboard, and you're all set for calculations.

For you, here is a calculator—with a memory, yet—one that you can fold up and put in your pocket, make copies of for all your working places, distribute to your friends, scale up or scale down as you please. Make a few copies right away; when one gets dirty and dog-eared, throw it away and use another. We call it "Nomorule."

Actually a generalized nomograph calculator, the Nomorule has one big advantage over a slide rule: memory. You can "store" mathematical operations as long as you need them for comparison and checking.

RADIO-ELECTRONICS has set up the Nomorule so you can simply cut it out and use it immediately, just as it is. But to keep it neat and accurate, you'll want to protect it.

Nomorule (Fig. 1) should be cut from the pages of this magazine and cemented to a hard surface, such as a bakelite board. Cover with a sheet of matte-finish Mylar or acetate (art supply stores), frosted side upward. The Mylar should be held firmly by a spring-loaded clamp fixed to the board. The scales must be well visible through the Mylar, so that you can trace alignments in tiny pencil lines on the frosted surface.

After you complete a problem, just remove the alignment tracings with a damp sponge, or erase with a soft eraser. If you want to keep the solution for further reference, you'll have to put at least two reference points on the Nomorule and the Mylar cover. Line them up perfectly before starting to "read out" the chart.

Fundamentals

Here are some of the principles on which Nomorule is based.

You can find the product (or quotient) of two numbers, A and B, by adding (or subtracting) their logarithms, like this:

$$\log(AB) = \log A + \log B$$

$$\log(A/B) = \log A - \log B$$

$$\log A^m = m(\log A) = -m\left(\log\frac{1}{A}\right)$$

$$\log \sqrt[n]{A} = (\log A)/n$$

In a nomogram, we add and subtract logarithmic calibrated scales *geometrically*, rather than by moving a slider within a frame as in a slide rule.

Consider a simple nomograph with vertical scales A, C, B, (Fig. 2). All scales are identical and equally spaced. Let a straight line intersect the scales at P, Q, R. Then the section O_2Q equals one-half the sum of sections O_1P plus O_3R. If the scales are logarithmic we

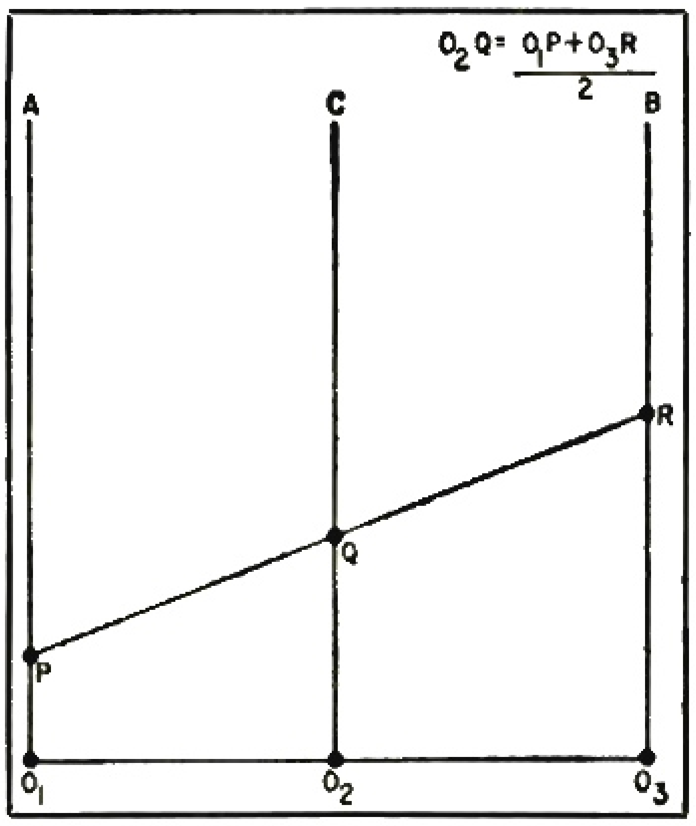

Fig. 2—Principle of the Nomorule: Length O_2Q is arithmetic mean of O_1P and O_3R. Hence O_2Q represents geometric mean.

have the relation, $Q = \sqrt{P \times R}$.

If we are interested in a product only (not its square root) we can change the calibration of middle scale C. We make its *modulus*, or unit length, equal to *one-half* the modulus of the other scales. Then log Q = log P + log R, or Q = P × R, directly.

The reciprocal of a number comes easily by using the two sides of the first scale, A and D, in Fig. 1. For example, D = 0.5 = ½, and A = 1/D = 2. The reverse, then, is also true—i.e., D = 1/A. Dividing by a number is the same as multiplying by its reciprocal. From B = AC, we get B/A = C which then becomes BD = C, since 1/A = D. The dotted line shows that 9 × 0.5 = 4.5, or BD = C.

Squares and square roots come out of scales B and E, cubes and cube roots from scales C and F. Other relationships,

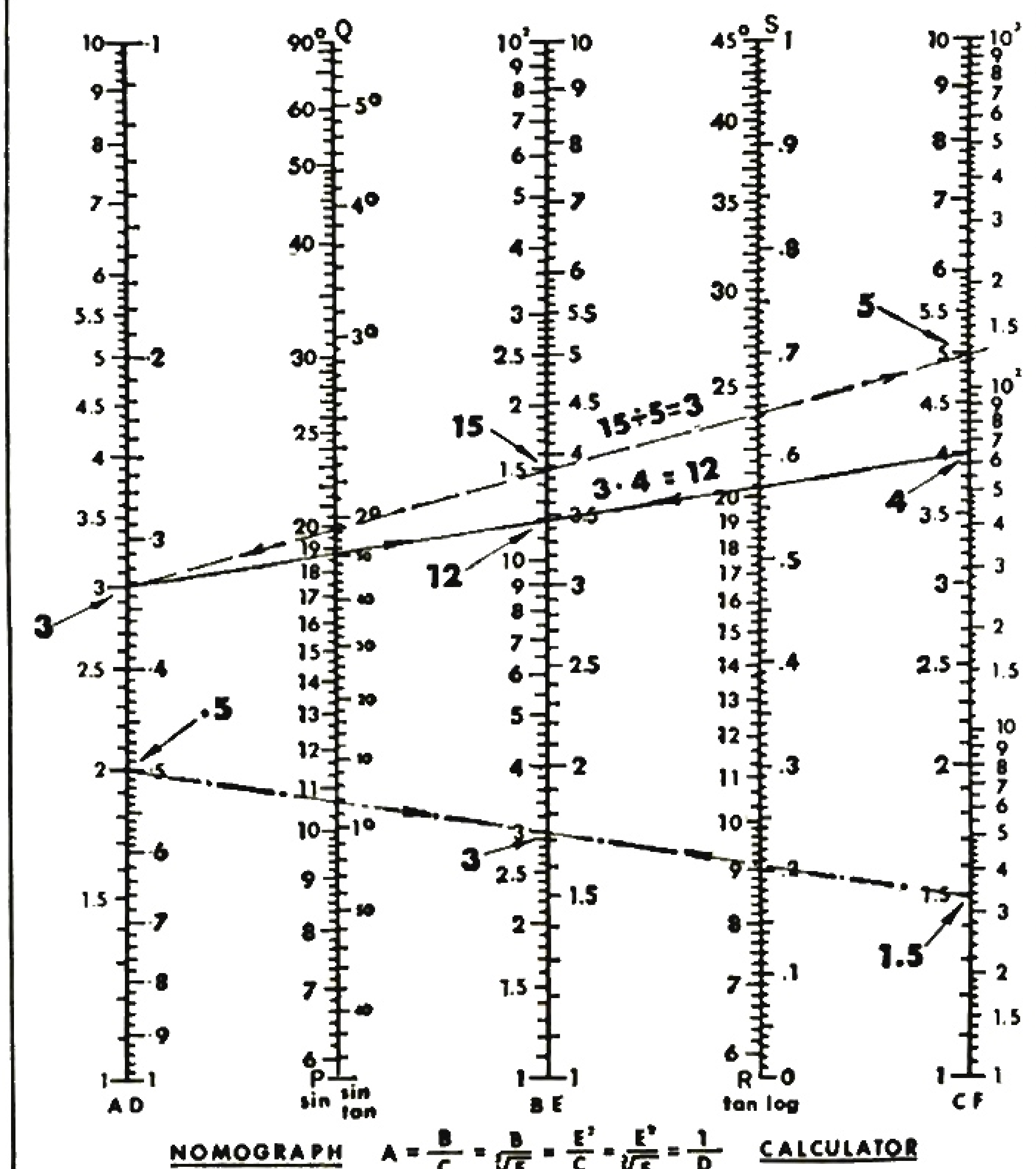

Fig. 3—Some simple examples of multiplication and division you can easily perform.

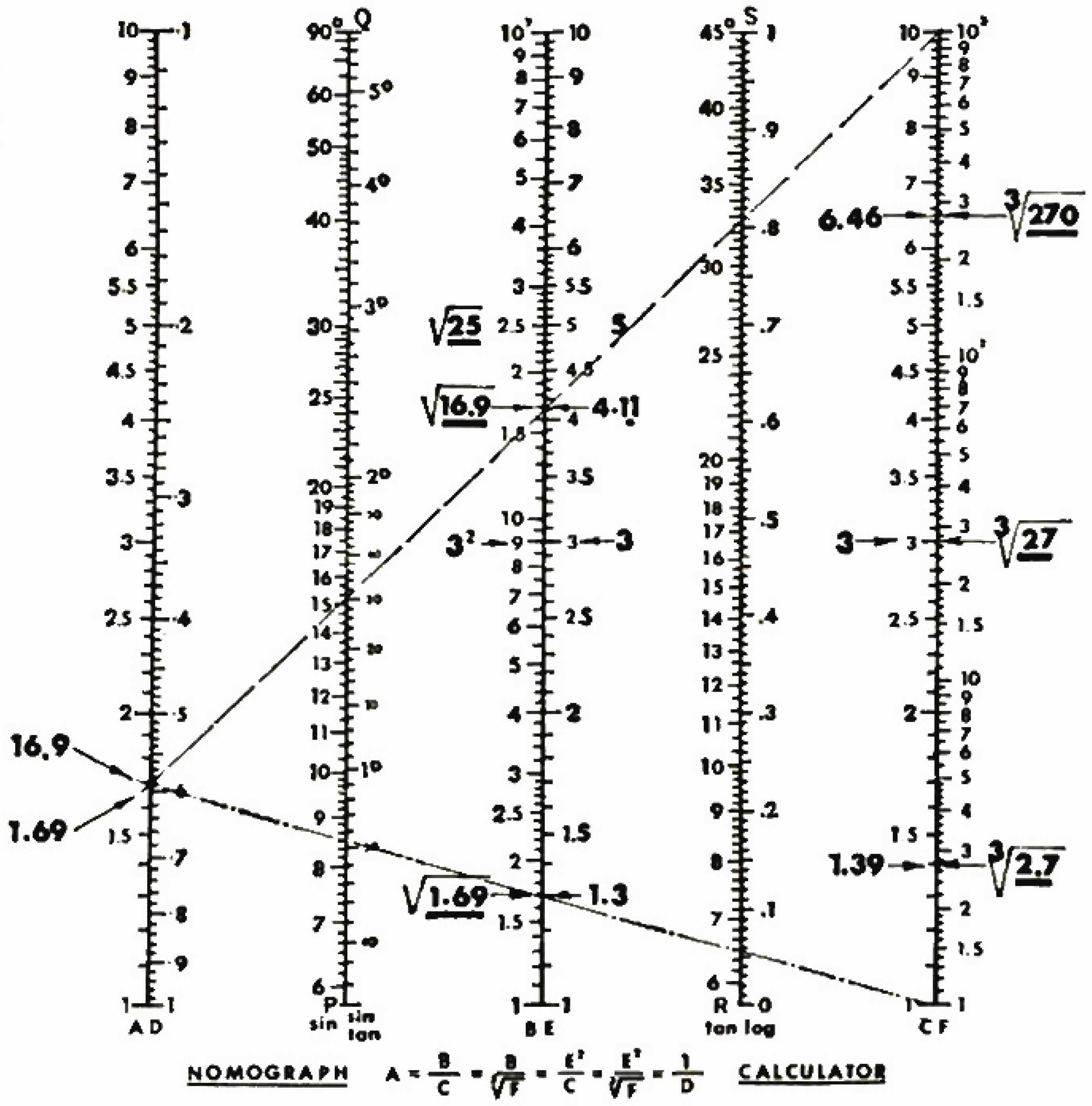

Fig. 4—The Nomorule is a real timesaver for extracting roots of squares and cubes.

including trigonometric and logarithmic functions, can also be read off. We'll come to that in a moment.

Basic operations

Once you know the basic rules, you can handle any combination of operations quickly and easily, and with sufficient accuracy for most practical problems.

Multiplication: Connect 3 (on A) with 4 (on C) to find 12 (on B). This is shown in Fig. 3, solid line.

Division: To find 15/5, intersect 15 (B) with 5 (C) to get 3 (A). This is shown by the dashed line in Fig. 3, and uses the equation B/C = A. Note that we chose 1.5 on the *higher* decade of B, above the 10, so it actually represents 15. Another way to divide is to apply the equation B = C/D mentioned earlier. Intersect 1.5 (C) with 0.5 (D) to obtain 3 (B) shown by the dot-dash line.

Finding the decimal point

Like a slide rule, the Nomorule determines numerical values, not the decimal position. But, as with a slide rule, finding the decimal point is easy.

Numbers can be expressed as some value between 1 and 10, multiplied by some power of 10. For example:

$$13{,}200 = 1.32 \times 10^4$$
$$.0061 = 6.1 \times 10^{-3}$$

To multiply these numbers, express the product as $1.32 \times 6.1 \times 10^{(4-3)}$. Using the nomorule, we find the answer is $8.05 \times 10 = 80.5$.

To divide 975 by .0003, express the numbers as

$$\frac{9.75 \times 10^2}{3 \times 10^{-4}}$$

and we obtain $3.25 \times 10^6 = 3{,}250{,}000$. As before, division of the significant digits is handled by the Nomorule. This result is multiplied by the proper power of 10.

Squares and square roots are read directly from scales B and E. Fig. 4 shows that $\sqrt{25} = 5$, and that $3^2 = 9$. Now let us find $1{,}200^2$. Write $1.2^2 \times (10^3)^2 = 1.44 \times 10^6 = 1{,}440{,}000$. To find $.003^2$, write $3^2 \times (10^{-3})^2 = 9 \times 10^{-6} = .000009$.

Take special care in extracting square roots. To find $\sqrt{169{,}000.}$ first split the number into groups of two digits each, beginning with the decimal point. This points off a number between 1 and 100, whose square root must lie between 1 and 10. Thus, $\sqrt{169{,}000.} = \sqrt{16|90|00.} = \sqrt{16.9} \times \sqrt{10^4} = 4.11 \times 10^2$. We cannot write 1.69 or 169, multiplied by some power of 10. Likewise $\sqrt{.0169}$ is written $\sqrt{.01|69} = \sqrt{1.69} \times \sqrt{10^{-2}} = 1.3 \times 10^{-1}$.

Squares may also be found by using scales A and E in conjunction with point 1 (C). For example, the dot-dash line (Fig. 4) shows that $\sqrt{1.69}$ (A) = 1.3 (E). The reason? We know that A = B/C and that B = E^2. Then A = E^2/C. When C = 1, A = E^2 directly. The same figure shows $4.11^2 = 16.9$, if we use 10 (C) as pole. We have used the equation A = E^2/10 in this case, so the answer on A (1.69) must be multiplied by 10 to arrive at the *correct* solution, 16.9.

C and F determine cubes and cube roots directly. Note that F has *three* decades, and we must use the correct one. For example, 2.7 is in the first decade, 27 in the second decade, 270 in the upper decade.

For cube roots of large numbers, first split the number into groups of three digits, beginning with the decimal point. For example, $\sqrt[3]{270|000.} = \sqrt[3]{270} \times \sqrt[3]{10^3}$; also $\sqrt[3]{.002|700} = \sqrt[3]{2.7} \times \sqrt[3]{10^{-3}}$. Then extract the roots.

Part 2 of this article will continue with scale transfer, trig functions, and other topics. TO BE CONTINUED

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THUNDERBOX PARTS HARD TO FIND?

A number of readers have reported difficulties in obtaining the Delco, Triad and Jensen components specified for the Thunderbox guitar amplifier described in the November issue. You can write to Mr. P. N. Cook, Triad Distributor Div., 305 N. Briant Street, Huntington, Ind. 46750; Mr. Hamlin Welling, Delco Radio Div., General Motors Corp., Kokomo, Ind. 46901; and Mr. Frank D. Lintern, Mgr, Consumer Products Div., Jensen Manufacturing Div., 6601 S. Laramie Ave., Chicago, Ill. 60638 for the name and address of their distributors in your area. Or, you can order from the following mail-order supply houses:

Newark Electronics Corp., 500 N. Pulaski Road, Chicago, Ill. 60624
Triad TY-160X Stock No. 4F450 $5.47
Triad R-206B Stock No. 4F453 $10.48

Allied Radio, 100 N. Western Ave., Chicago, Ill. 60680
Triad TY-160X Stock No. 54 D 3536 $5.47
Triad R-206B Stock No. 54 J 3538 $10.48

Harvey Radio, 2 W. 44th St., New York, N.Y. 10036

Delco transistor DTG-110B	$2.70 ea.
(Specify that both transistors have the same color code.)	
Delco heat sink No. 7270725	$0.90 ea.
1N3209 silicon diode	$1.77 ea.
1N3209R silicon diode	$1.77 ea.
Jensen EM-1250 speaker	$34.62

The Nomorule in Electronic Calculations

Part 2—More uses for last month's Nomorule: How to multiply and divide by using logarithms; trig functions and some practical examples

By JOHN H. FASAL*

THE BASIC NOMORULE DESCRIBED IN PART 1 is repeated here as Fig. 1. We showed that you can multiply two numbers by aligning a straightedge across one on scale A and the other on scale C, and reading off the product on scale B. If you have more than two factors, you must transfer the first product back to either scale A or scale C, to use it as a

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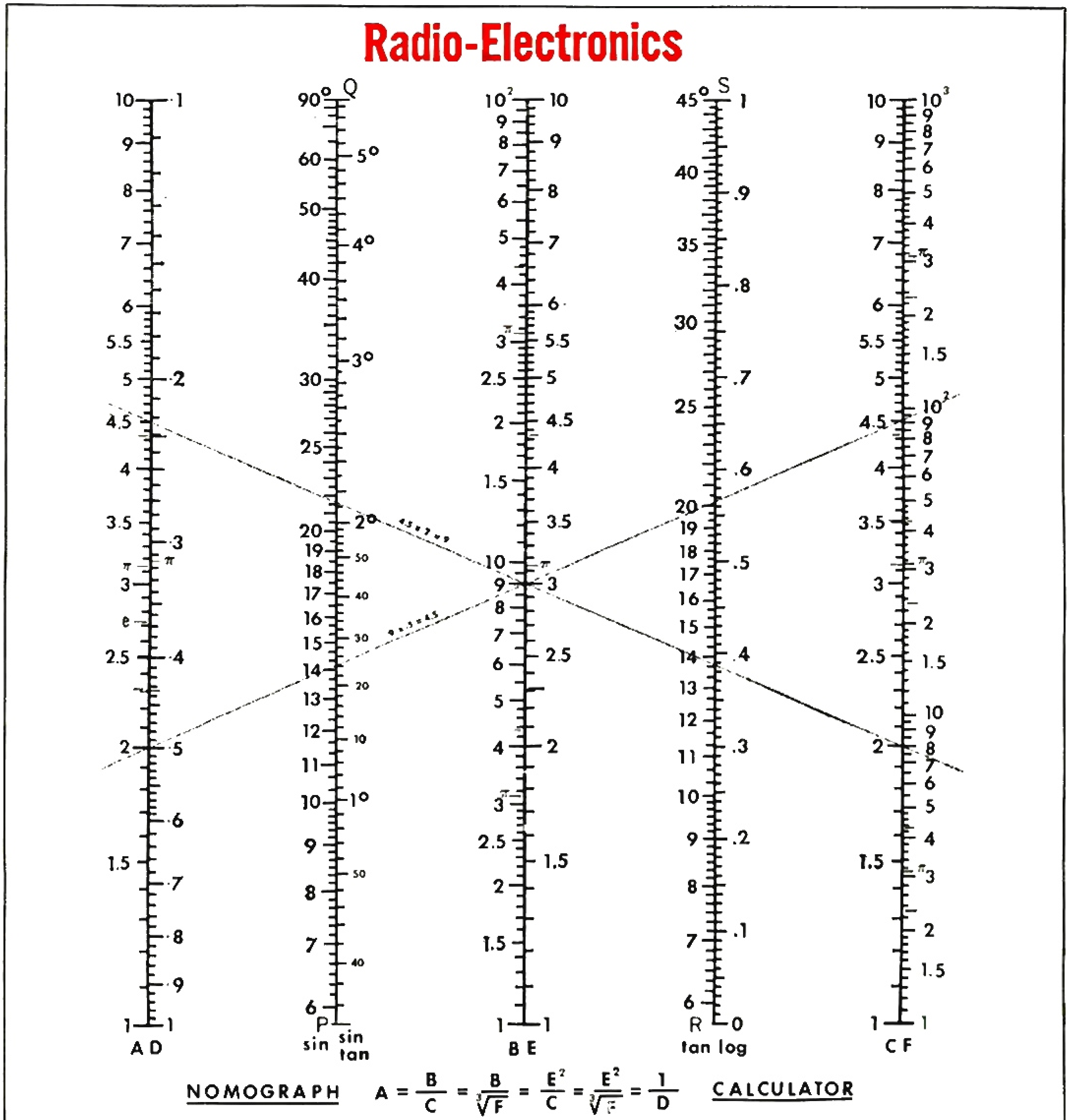


Fig. 1—Here is the Nomorule again, repeated from last month. Cut out and mount it on cardboard.

factor in the next product.

If any number at B is aligned with 1 on scale C, the line will intersect the same number at A. This is true because B = AC, and in this case C = 1, so B = A. Thus we can transfer the number from B to A without changing it.

We can also transfer a number from B to C. Let a line intersect the number at B with the top index (0.1) at D. At C we will find 0.1 B. The equation used is C = B/A = BD, and D = 0.1 in this case. We must remember to multiply the transferred number (A) by 10 to make it equal the original number at B.

Another transfer is possible using 10 on scale C as pole (or pivot point). Align it with the number at B, and find the answer at A. We are using the equation A = B/C with C = 10. Therefore A will be 0.1 B and it must be multiplied by 10 to equal B.

The Nomorule is ideally suited for calculations with trigonometric functions. To find the sine of an angle (such as 30°) look for the angle on the "sin" scale and align it with either point R or point S on the fourth scale (Fig. 2). The answer is found on B, the center scale. Values of sine for angles between 6° and 90° lie between 0.1 and 1. For better accuracy, align with point R if the angle is smaller than 18° (midway up the "sin" scale). Use S for angles larger than 18°.

Sine or tangent values for smaller angles, between 36′ and 6°, are based on the "sin-tan" scale and are calculated in the same way. All readings found on the B scale, lie between .01 and 0.1.

To find the tangent of an angle larger than 6° use the "tan" scale. Align the given angle (for example, 20° as shown) with either point P or point Q of the second scale. The answer is tan 20° = 0.364, as shown in Fig. 3. An angle smaller than 45° has a tangent smaller than 1.

When the angle is greater than 45°, use the equation tan B = cot (90 − B) = 1/tan (90 − B). For example, tan 70° = cot 20° = 1/tan 20°. To find tan 70°, determine tan 20°. Transfer the reading from B to the inverse scale D as shown by the phantom lines of Fig. 3. In other words, we have transferred tan 20° to scale A, then found its reciprocal at D. This indicates 1/tan 20° or tan 70°, which is 2.74.

For cotangents of angles smaller than 45°, use the formula cot B = 1/tan B. Determine tan B on scale B, then transfer reading to inverse scale D. For angles larger than 45°, use cot B = tan (90 − B). The reading appears on scale B directly.

You can find common logarithms by using the "log" scale with point P or point Q on the second scale, and the B scale. Align the number (for example, 6) at scale B with P or Q and read off the logarithm on the "log" scale, as 0.78. To find log 6,000, write it as 6 × 10^3, and *add* the corresponding logs. The answer is 3.78. Log 2 is also shown in Fig. 4: 0.301.

Now how about a couple of practical electronic examples worked out on the Nomorule? Let's say we want to find the resonant frequency of a circuit having L = 2.5 × 10^{-1} henries and C = 1.6 × 10^{-9} farads. The frequency is

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{10^5}{2\pi\sqrt{2.5 \times 1.6}}$$

Align 2.5 on scale A with 1.6 on scale C, as in Fig. 5, and find the product 4 on scale B. The square root is read off directly as 2 on scale E. A point on scale B may be transferred to either scale A or C, as we've said before. But you can't do it that way from E. Instead, use a "cross alignment" onto scale C, like this: Connect 2 on scale E with (1) on scale C, intersecting the "tan" scale. Through this intersection draw a line through 1 on scale E, giving a point on C which is identical to the original point on E.

The next step is to multiply by 2π on A. This gives us 12.56 (scale B). Transfer this value to A, using 10 (scale C) as pole. We are using the relation A = B/C where C is 10. Therefore, the value at A has been reduced by a factor of 10. It is restored to its correct value by multiplying by 10. Instead of 1.256 (scale A) we actually have 12.56. The last step is to find the reciprocal of 12.56, which is .0795 (scale D). Multiplying by 10^5 (see formula above), we get the frequency: 7.95 kHz.

Several problems are worked out in Fig. 6. The inductive reactance of a coil (X_L) is given by ωL where ω is 2πf. Let f = 6 × 10, and L = 5.6 × 10^{-1}.

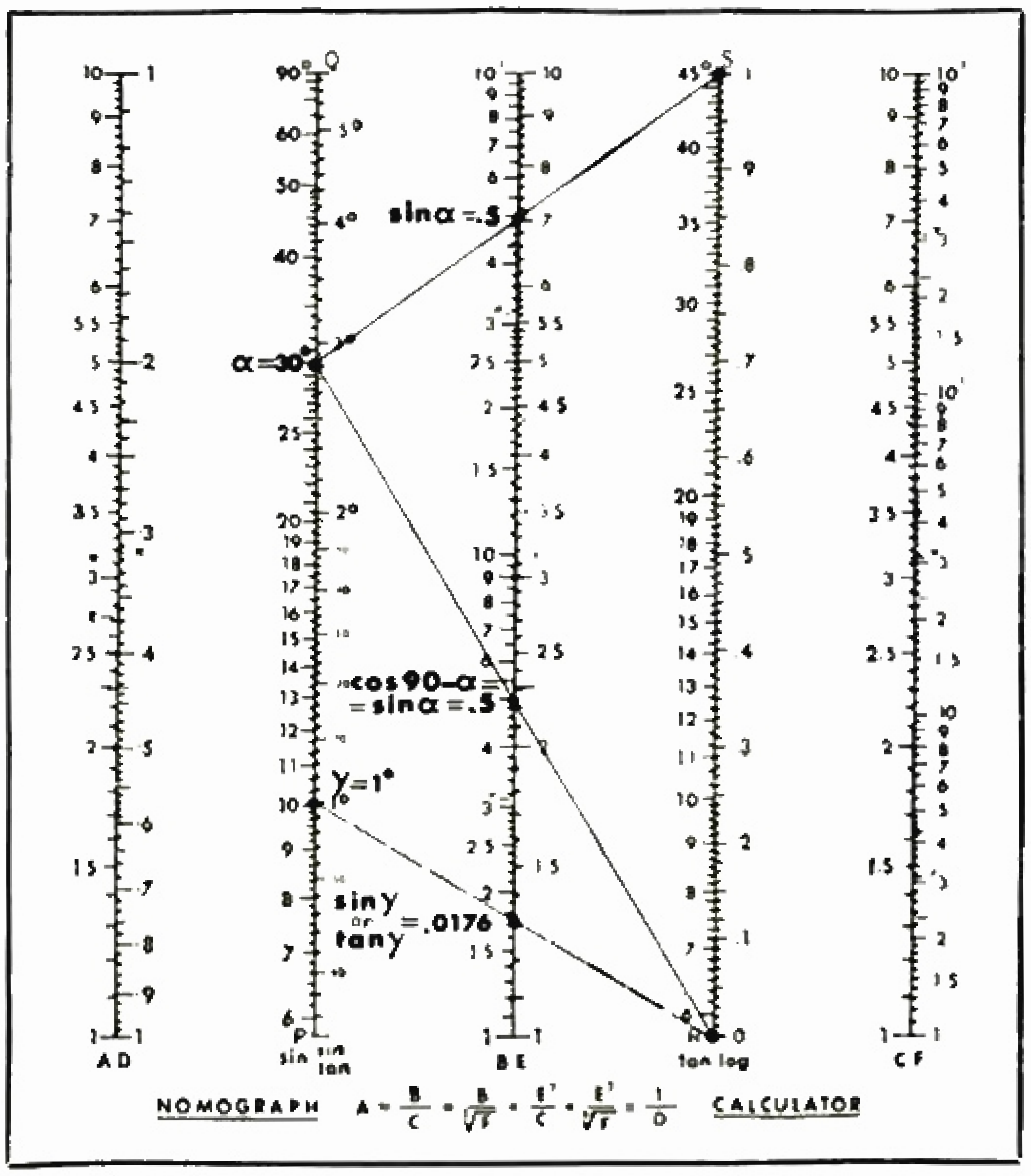


Fig. 2—Finding sine of any angle, or tangent of a small angle.

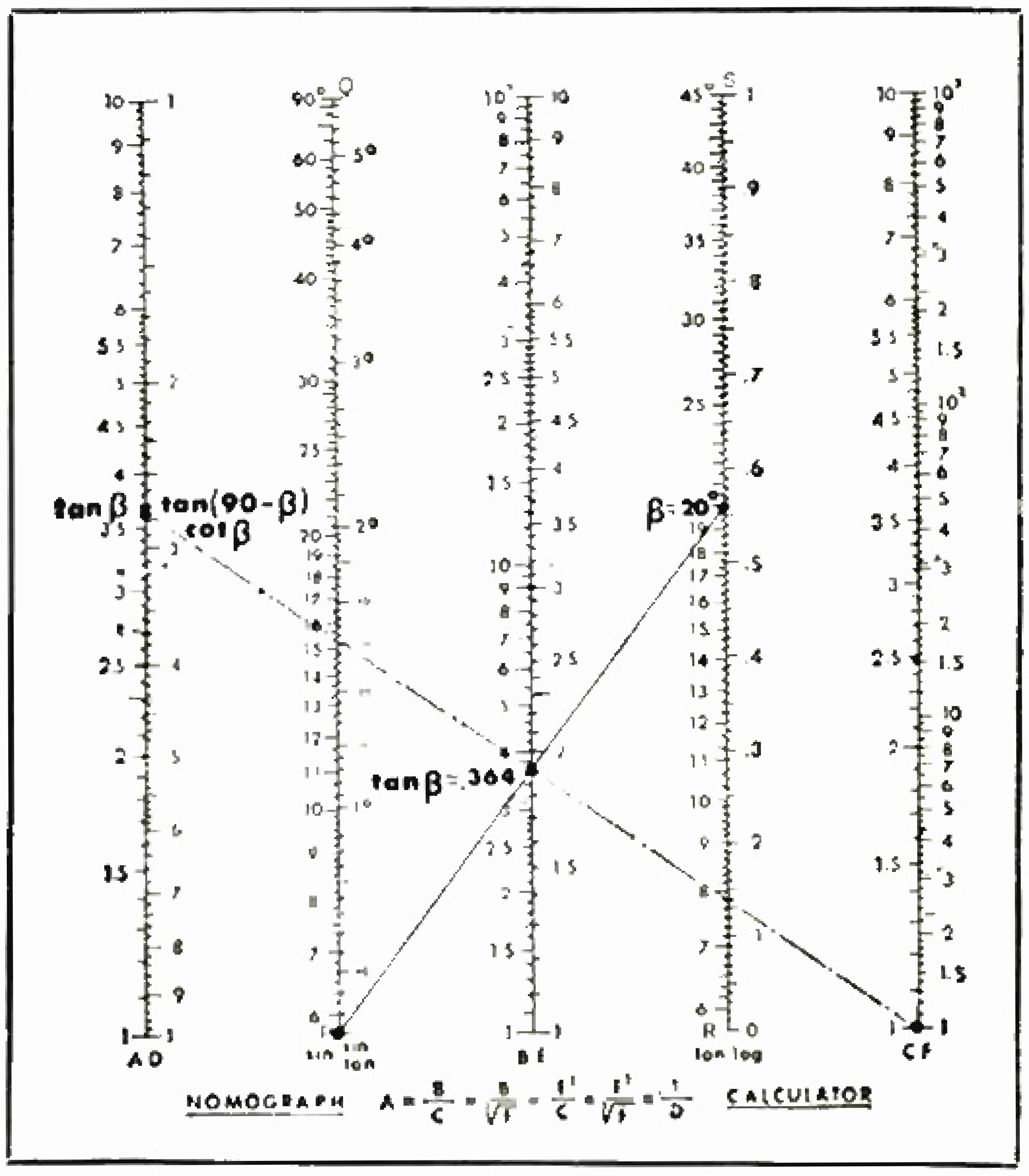
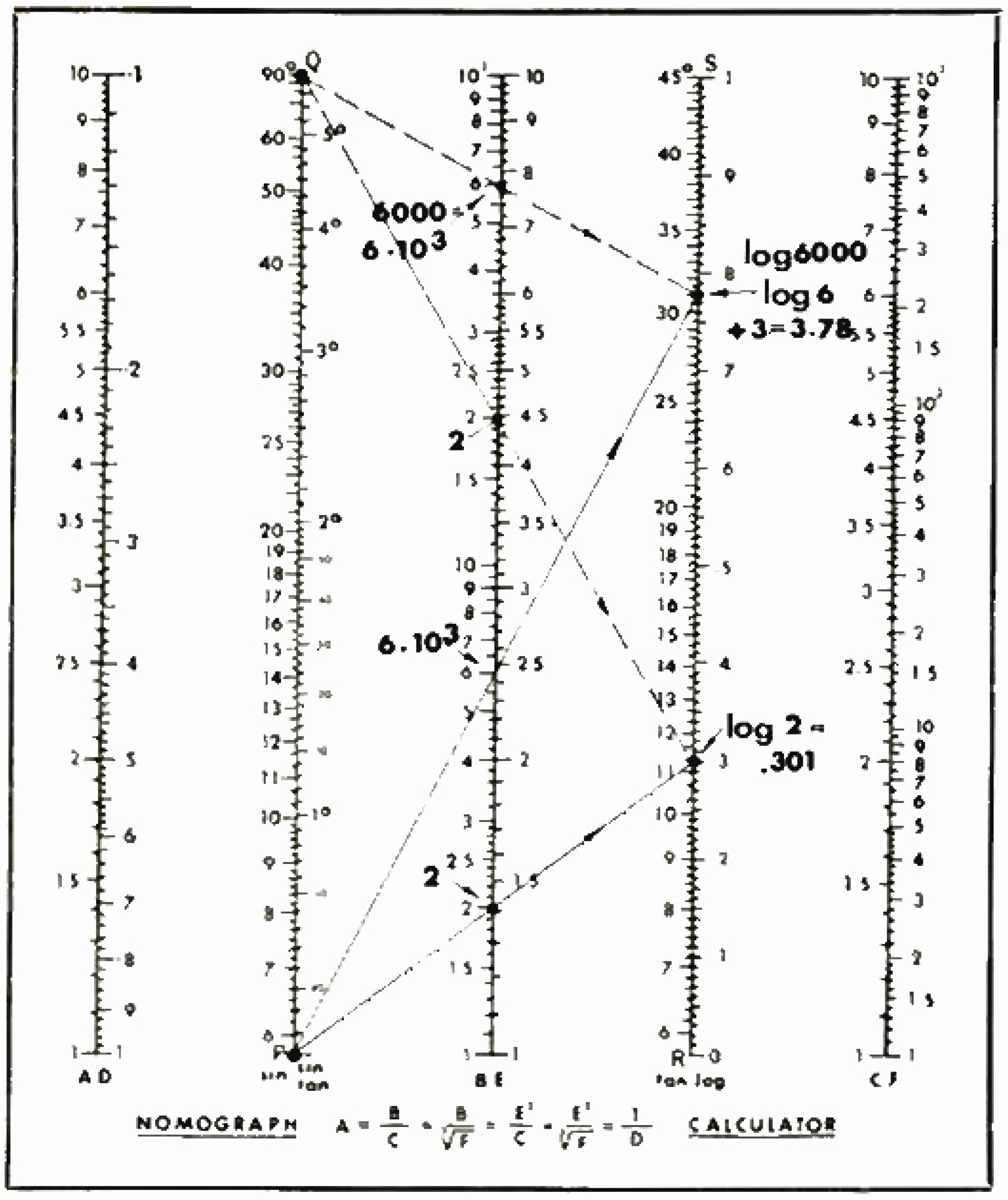


Fig. 3—Tangents and cotangents are determined like this.



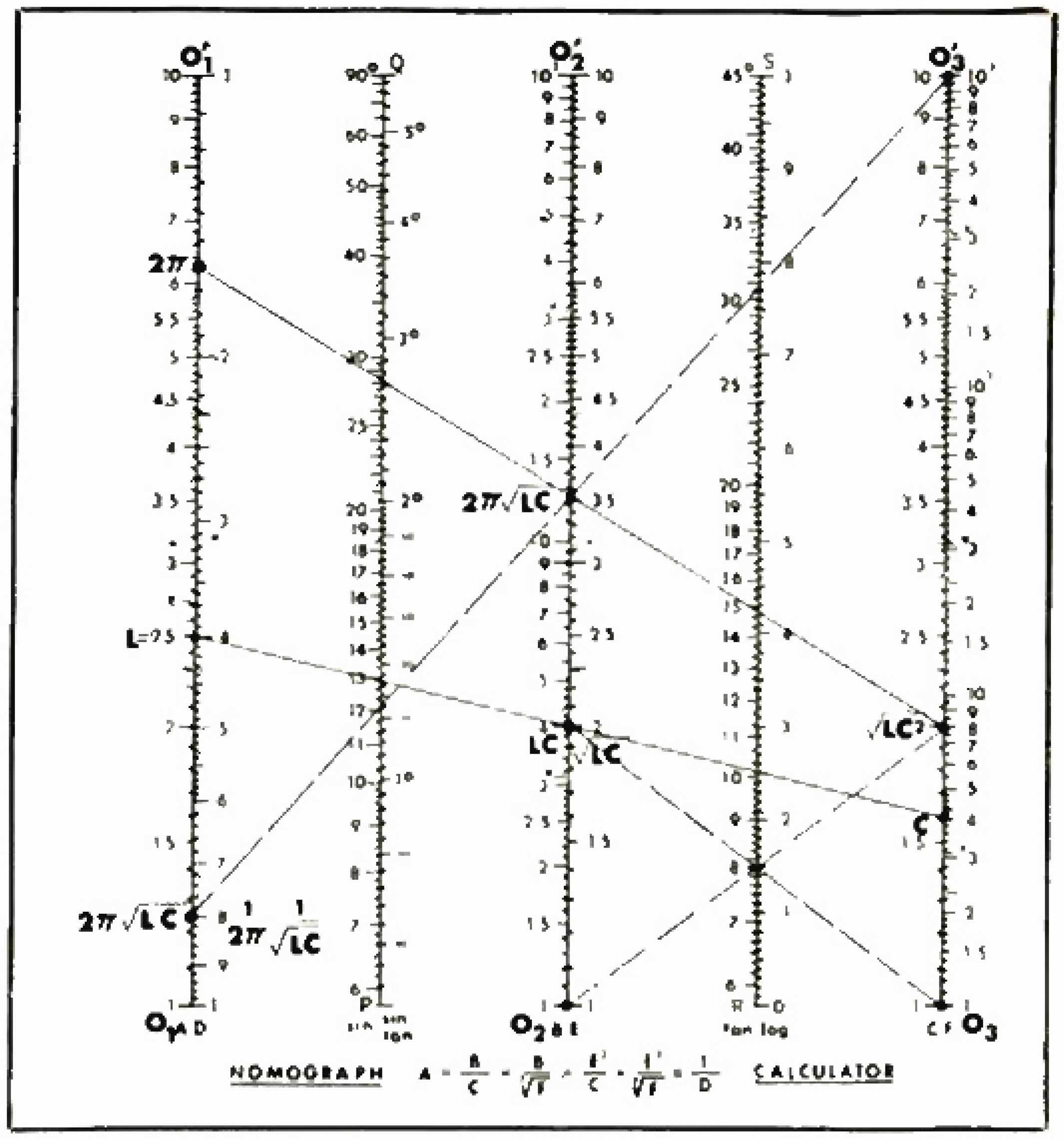


Fig. 5—Working the resonance formula with the Nomorule.
Fig. 4—How to read the logarithm of a number (at the left).

The Nomorule in Electronic Calculations

First find $2\pi f = 37.7 \times 10$ as shown. Now transfer this result from B to A, using 10 on C as pole. We know that this transfer divides the number by 10, so we must multiply by 10 to compensate. We have, therefore, 3.77×10^2 at A. Now multiply this by the value of L (at C) and obtain the reactance as 21.1×10 at scale B.

Other examples in Fig. 6 show how to convert frequency to wavelength. The formula is $f = \frac{300{,}000}{\lambda}$, where f is in kHz, λ in meters, and 300,000 is the velocity of light in km/sec. The Nomorule shows that 416 meters corresponds to 720 kHz; 857 meters corresponds to 350 kHz and 250 meters to 1.2 MHz.

As a last example, let us calculate the Q at 5 kHz of a coil with 0.4 henry inductance and 628 ohms resistance, in accordance with the formula $Q = \frac{2\pi fL}{R} = \frac{2\pi(5 \times 10^3)(4 \times 10^{-1})}{628}$. Fig. 7 shows how. The first product is read off as 31.4×10^3 on B. Transfer this result to C by using the top index (0.1) on D as pole. Line TR shows this. Align this result with 4×10^{-1} at A, and we find 12.56×10^3 at B. Transfer this to C (line TR′), then divide by 0.628×10^2 at D. The result is 2×10. END

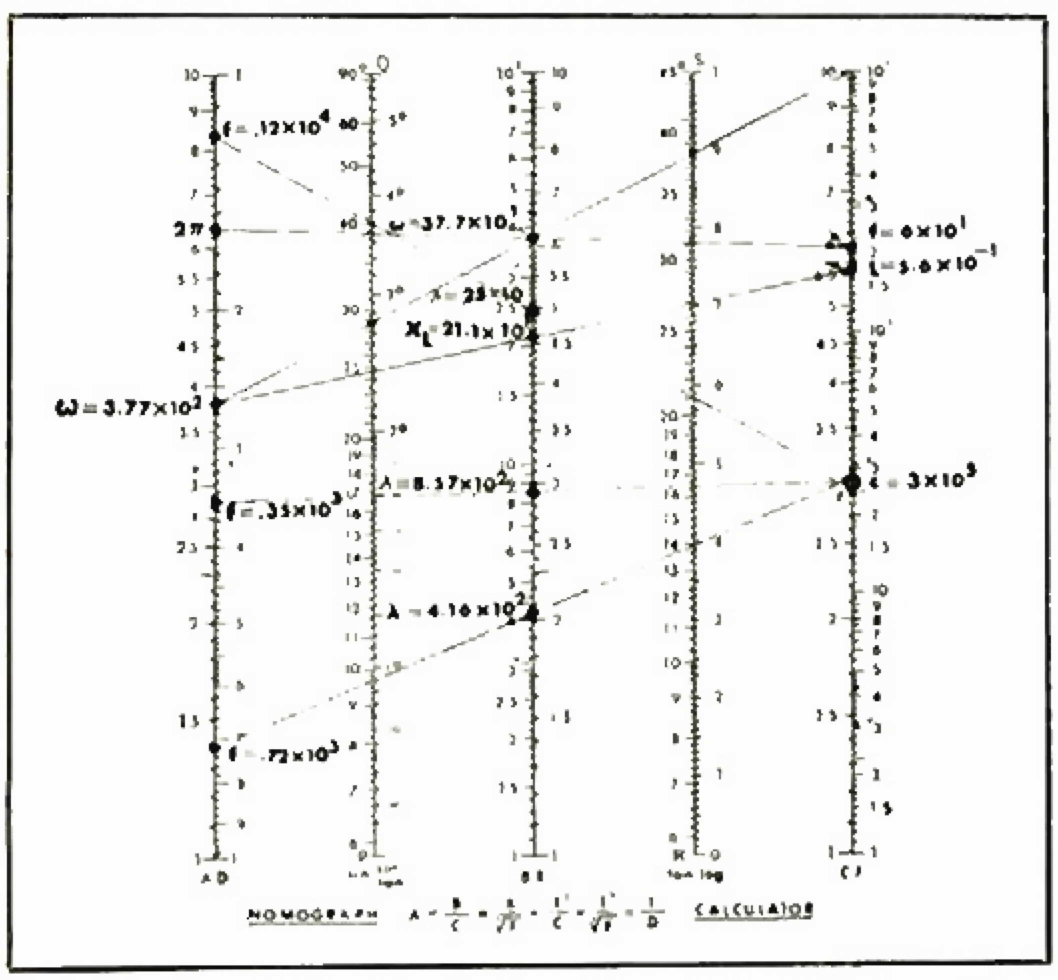


Fig. 6—Inductive-reactance, frequency/wavelength problems.

Fig. 7—Rapid method of calculating the Q factor of a coil.