Dec. 6, 1938. R. B. POOLE 2,138,879

SLIDE RULE

Filed Nov. 28, 1936 2 Sheets-Sheet 1

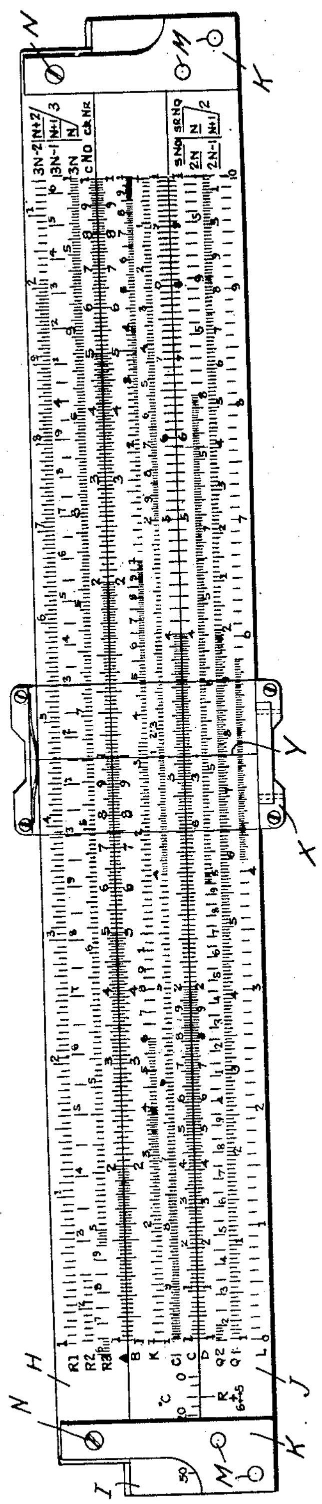

FIG. 1.

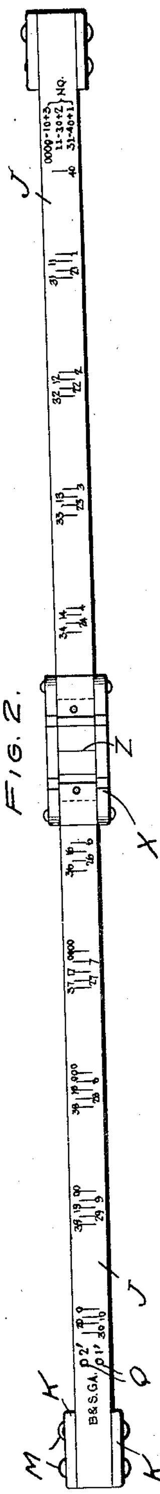

FIG. 2.

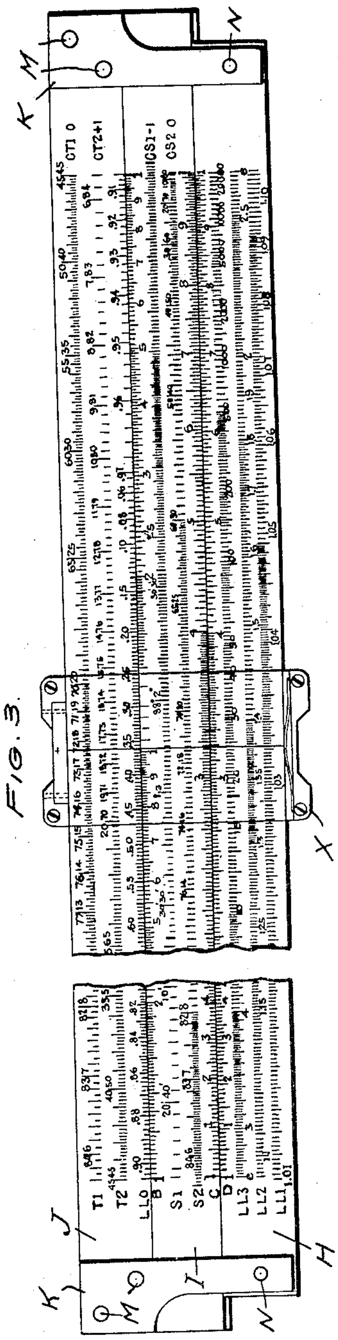

FIG. 3.

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SLIDE RULE

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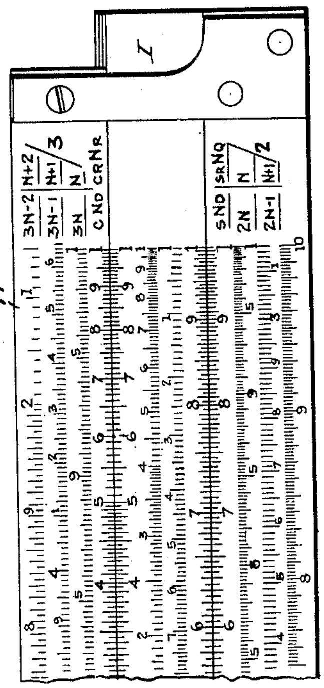

FIG. 5.

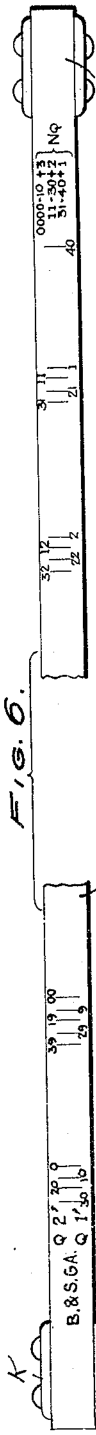

FIG. 6.

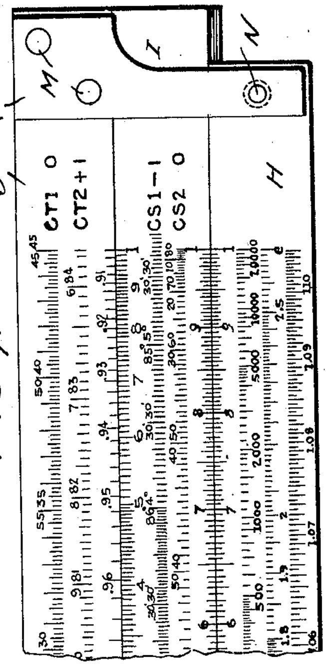

FIG. 7.

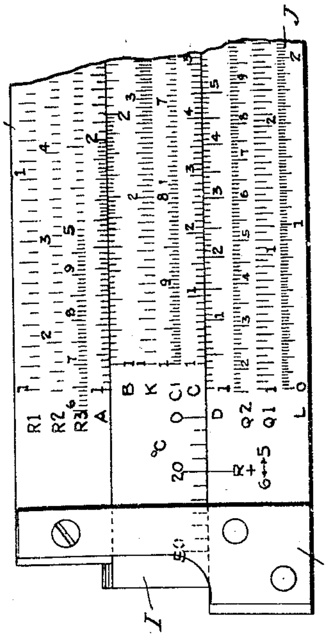

FIG. 4.

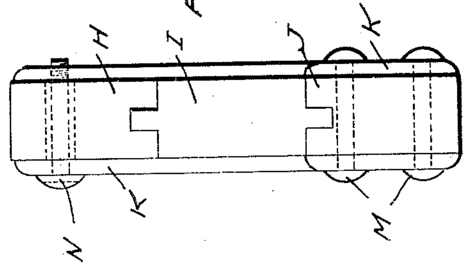

FIG. 8.

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UNITED STATES PATENT OFFICE

2,138,879

SLIDE RULE

Roy B. Poole, Dayton, Ohio

Application November 28, 1936, Serial No. 113,238

6 Claims. (Cl. 235—70)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

My invention relates to slide rules and more particularly to a log log duplex slide rule, and the novelty thereof consists of improvement in the scales and their arrangement as will be more fully hereinafter pointed out.

A further object of my invention is to provide a slide rule by means of which numerical computations of an engineering nature can be solved with greater ease, more rapidly, and with greater accuracy than with any slide rule heretofore in use.

With the foregoing and other objects in view, which will appear as the description proceeds, the invention consists of certain new and novel features and combinations, which will be hereinafter more fully illustrated and described in the accompanying drawings and more particularly pointed out in the appended claims.

Referring to the drawings, in which numerals of like character designate similar parts throughout the several claims:

Fig. 1 shows the front working face of my slide rule.

Fig. 2 shows the bottom edge of Fig. 1 in side profile.

Fig. 3 shows the rear working face of my slide rule.

Fig. 4 shows an enlarged left-hand portion of Fig. 1 with special setting of the sliding bar.

Fig. 5 shows an enlarged right-hand portion of Fig. 1.

Fig. 6 shows an enlarged fragmental view of Fig. 2.

Fig. 7 shows an enlarged right-hand portion of Fig. 3.

Fig. 8 shows a further enlarged end view of the right-hand portion of Fig. 1.

In Fig. 1, four plates K are fixed to the outer extremities of a bar J by means of rivets M. The bar J is surmounted by a sliding bar I, which, in turn, is surmounted by a bar H. The last-named bar is varyingly adjusted, then fixed, with respect to the upper ends of the plates K by means of screws N. Referring to Fig. 8, the slidable bar I has the usual tongue members on each edge thereof, adapted to slide in the usual groove members furnished on the inwardly disposed edges of the bars H and J. Thus the sliding bar I is firmly secured against lateral movement and at the same time is freely longitudinally slidable with respect to the fixed bars H and J. An indicator X, with full transparent surfaces overlaying the rule markings of Figs. 1 and 3 and a third transparent surface overlaying the rule markings of Fig. 2, is freely slidably mounted upon the aforesaid bars such that it may be readily adjusted to any predetermined position between the plates K. The side transparent surfaces of the indicator X are provided with the customary hair lines Y, while the bottom transparent surface of the indicator X is provided with a hair line Z.

In Fig. 1, the upper portion of the bar H is provided with a folded logarithmic scale designated R1, R2 and R3, the total length thereof being three times that of the standard "D" scale. The special purpose of this arrangement, as well as the use of certain "markings" appearing to the extreme right thereof, will be discussed in detail below. The next scale on the bar H is the standard "A" scale consisting of the usual graduated logarithmic scale of two unit lengths from "1" to "100".

For its uppermost scale, the sliding bar I is provided with the standard "B" scale, graduated the same as scale "A" on bar H. Immediately beneath the "B" scale is positioned the standard "K" scale, consisting of three complete logarithmic scales. The third scale on the sliding bar I is the standard "CI" which is the usual reciprocal logarithmic scale of full unit length, graduated from "10" to "1". The fourth and last scale on the sliding bar I is the standard "C" scale, graduated logarithmically and of full unit length from "1" to "10".

The bar J of Fig. 1 is provided with four scales as follows: The uppermost scale is the standard "D" scale, graduated logarithmically, exactly the same as the "C" scale on the sliding bar I. Immediately below the "D" scale is provided a folded logarithmic scale designated Q2 and Q1, the total length being twice that of the standard "D" scale. The use of certain "markings" appearing to the extreme right of the aforesaid scales, and used in conjunction therewith, will be discussed below. The fourth and last scale on the bar J is the standard equal parts "L" scale. The further use of certain markings appearing to the extreme left of the four scales referred to above will be discussed in detail below.

It is now pertinent that reference be made to the new and novel arrangement of certain of the "scales" and all of the "markings" disclosed in Fig. 1. By means of the novel arrangement, the folded scale designated R1, R2 and R3; with the indicator X set to any desired number thereon, the cube of the aforesaid number can be determined directly below on the "D" scale, or conversely; for any setting on the "D" scale, the corresponding cube root of the aforesaid number can be read directly on the folded scale designated R1, R2 and R3. Since the latter is arranged in three folds, a new and novel introduction of "markings" has been incorporated upon the extreme right-hand portion of the bar H, the purpose of which is to provide an abbreviation of the rules for determining the decimal point in the calculation proposed, which "markings" further serve to indicate which one of the aforesaid three folds the result should be read on.

As shown in Fig. 1, the "A" and "B" scales occupy their usual position. The "K" scale, however, is moved to the sliding bar I and takes the place of the standard "CIF" scale, which is a full length inverted "CF" scale, folded on the vertical center line of the sliding bar I. The foregoing arrangement facilitates the evaluation of such expressions as

$$''a\sqrt[3]{b\times c}'',$$

etc. It should further be noted that the "C", "CI" and "D" scales occupy their normal positions.

Through the new and novel interarrangement of the "D" scale and the folded Q2 and Q1 scale, the square of any number read on the latter scale is found on the former scale by means of the indicator X and conversely, the square root of any number on the "D" scale is obtained directly below on the Q2 and Q1 scale. Since the latter is arranged in two folds, a new and novel introduction of "markings" has been incorporated upon the extreme right-hand portion of the bar J to indicate, thru appropriate rule abbreviations, which one of the aforesaid two folds the result should be read on, and for the further purpose of determining the decimal point in the calculation proposed. Following conventional practice, the "L" scale of equal parts is placed below the Q2 and Q1 scale. The common or Briggs logarithm of any number on the "D" scale is read on the "L" scale by means of the indicator X.

A further new and novel auxiliary, or offset scale designated °C., covering a range from right-to-left of zero to fifty degrees centigrade, is positioned upon the lowermost left-hand portion of the sliding bar I and is adapted for alignment with a reference line designated R positioned upon the uppermost left-hand portion of the bar J. By means of the aforesaid scale °C. and reference line R, the electrical resistance of copper bar or wire per 1000 foot length can be readily obtained, in terms of the international standard, for any temperature of from 0° C. to 50° C., and for any given diameter or area in circular mils. The foregoing is accomplished by bringing the desired temperature on the °C. scale into coincidence with the reference line R, then setting the indicator X to the bar or wire diameter required on the Q2 and Q1 scale. The desired resistance per 1000 feet can then be read on the "CI" scale. Determination of the decimal point from the "markings" appearing to the right of the Q2 and Q1 scale has previously been discussed hereinabove.

In Fig. 2, the lower portion of the bar J shown in Fig. 1 is provided with a secondary Q2' and Q1' scale, the Q2' fold appearing upon the upper portion and the Q1' fold appearing upon the lower portion of the bar J. In accordance with the Brown and Sharpe system of wire gauges, sizes from "1" to "10", are read from extreme right to extreme left on the Q1' fold. If the indicator X be set on "1", a corresponding mil reading of 289 is obtained on the Q1 fold of Fig. 1. In like manner, with indicator X set to "5" or "10" on the Q1' fold, corresponding mil readings of "182" and "102", respectively, are obtained on the Q1 fold of Fig. 1. Wire gauge sizes from "11" to "20" are read from extreme right to extreme left on the Q2' fold. The remaining gauge sizes of "21" to "30" and "31" to "40" are found respectively upon the Q1' and Q2' folds. The remaining wire gauges of "0" to "0000" are found upon the left-hand extremity of the Q2' fold. The special significance of certain "markings" appearing to the extreme right of the Q1' and Q2' scale will be discussed in detail below.

In Fig. 3, the upper portion of the bar J is provided with a folded scale designated (left) T1 and T2 and (right) CT1 and CT2, the total length thereof being twice that of the standard trigonometrical "T" scale of tangents. Numerical values of tangents obtainable from the first fold thereof have a range from 0.1 to 1.0, whereas those obtained from the second fold range from 1.0 to 10.0. It should be noted that all figures referring to co-functions are in red, as are the designations CT1 and CT2 appearing at the extreme right-hand portion of the bar J. The special significance of the "0" and "+1" markings appended thereto will be discussed in detail below. Immediately beneath the above folded scale is positioned a standard "LLO" scale giving graduated log-log fractional or decimal readings from .05 to .97.

The "B" and "C" scale positioning of the bar I shown in Fig. 1 has been retained in Fig. 3. Between these scales is interposed a folded scale designated (left) S1 and S2 and (right) CS1 and CS2, the total length thereof being twice that of the standard trigonometrical "S" scale of sines. The numerical values of sines read upon the first fold thereof range from 0.01 to 0.10, whereas those read from the second fold range from 0.10 to 1.0. It should be noted that all figures referring to co-functions are in red, as are the designations "CS1" and "CS2" appearing at the extreme right-hand portion of the bar J. The special significance of the "−1" and "0" markings appended thereto will be discussed in detail below.

The bar H of Fig. 3 is identical in its upper scale arrangement to that of the bar J of Fig. 1. Immediately beneath the "D" scale is provided a folded scale designated "LL3", "LL2" and "LL1"; the first fold thereof being graduated through the numerical range from 2.718 to 22,000 or e^1 to e^{10}; the second from 1.105 to 2.718 or $e^{1/10}$ to e^1; and the third from 1.01 to 1.105 or $e^{1/100}$ to $e^{1/10}$.

Reference is now made to new and novel arrangements of certain of the "scales" and all of the "markings" disclosed in Fig. 3. By interarrangement of the folded T1 and T2 scale and the standard "D" scale upon the fixed upper and lower bars J and H, respectively, and by further interarrangement of the folded S1 and S2 scale and the standard "C" scale upon common sliding bar I; tangent and co-tangent values can be read directly upon the "D" scale and sine and cosine values read directly upon the "C" scale by means of the indicator X. This is thought to be a distinct advancement in the art.

The following examples, showing my new and novel method of accomplishing certain engineering calculations are given, to more clearly set forth the nature and scope of my improved slide rule. Before proceeding with the actual examples, and in order to simplify the description of slide rule operations, we will make use of a symbolic notation in which—

n=any given number.

N=the characteristic of any number (n).

Na=the characteristic of any number (a).

Nb=the characteristic of any number (b), etc.

a, b, c, d, e and so on represent numbers used in any numerical calculation.

Like its logarithmic analogy, the characteristic of a number, for slide rule purposes, can be defined a follows:

Number	Characteristic	Number	Characteristic
$a=2$ $b=20$ $c=2\times10^5$ $d=n$	$Na=1$ $Nb=2$ $Nc=(1+5)=6$ $Nd=N$	$a=.2$ $b=.02$ $c=2\times10^{-5}$ $d=-n$	$Na=0$ $Nb=-1$ $Nc=(1-5)=-4$ $Nd=-N$

Where N=number of digits in the number (n).
Where N=number of 0's preceding the number (n).

Referring to the folded scale R1, R2, R3 and more particularly to the "markings" previously noted, as shown in Fig. 5 and appearing to extreme right thereof; the purpose of the latter will now be made clear. It will be observed that these "markings" are arranged in two columns separated by a vertical line; the group to the left of this line being an abbreviation of the rules for determining the characteristic, or decimal point location of any number whose cube is obtained by setting the indicator X to the given number on R1, R2 or R3, and reading the result on "D". Likewise, the group to the right of this vertical dividing line is an abbreviation of the rules for determining the characteristic, or decimal point location of any number whose cube root is obtained, by setting the indicator X to any given number on "D" and reading the result on R1, R2 or R3. Considering the left group, it will further be observed that the notation 3N, 3N—1 and 3N—2 lines up respectively with scales R3, R2 and R1. The key to this group is placed immediately below and adjacent to the slide I; the notation "CND" meaning the cube, or characteristic of the cube of any given number read on the "D" scale. The group to the right of the dividing line has the notation N, N+1 and N+2 lining up respectively with scales R3, R2, and R1; and it is evident that, for any characteristic of N, one of these and only one will be divisible by three as indicated. The relation of (N)/3, (N+1)/3 and (N+2)/3 to the adjoining scales R3, R2 and R1 is necessary to the correct reading of a cube root on these scales, as it serves to show clearly which section of the scale the result must be read on, as well as giving the characteristic of the result. For example, by taking a series of numbers from 1 to 1000, it is noted that the cube root of any number from "1" to "10" is read on the R1 scale, since in this case N=1 and (N+2)/3=1 as required for this scale. Likewise, the cube root of any number from 10 to 100 is read on the R2 scale, for N=2 and (N+1)/3=1 as required; also the cube root of any number from 100 to 1000 is read on the R3 scale, for N=3 and N/3=1 as required. The key to this group of "markings" "CRNR" means the cube root, or characteristic of the cube root of any given number read on scale R1, R2, or R3. Whereas this group of "markings" is indispensable to the correct reading of a cube root on the R1, R2 or R3 scale, the reverse is not true; i. e., the correct reading for a cube on the "D" scale is always obtained without reference to the "markings". The latter is used merely for the purpose of determining the characteristic of the resultant cube as previously explained.

Illustrative Examples

Cubes of numbers using scales R1, R2, R3 and "D"

Rule 1.—If the given number is read on R1, the characteristic of its cube read on "D" is 3 times that of the number less 2; if on R2, it is 3 times that of the number less 1; and if on R3, it is 3 times that of the number.

Let $a^3=x$

Top scale R1	Intermediate scale R2	Lower scale R3
$Nx=3Na-2$	$Nx=3Na-1$	$Nx=3Na$

To find the cube of a number, set the indicator to the given number on R1, R2 or R3, then the coinciding number read on "D" is the cube; the characteristic being determined by Rule 1.

Examples of cubes using scales R1, R2, R3 and "D" (Rule 1)

1. $(20.4)^3=8490$
2. $(30,500)^3=28.4\times10^{12}$
3. $(.00876)^3=.000000672$

$N=(3\times2)-2=4$

$N=(3\times5)-1=14$

$N=3(-2)=-6$

4. Find the volume and weight of a steel ball 6.5 inches diameter, assuming that steel weighs 0.28 lb. per cu. in. Volume $V=.5236d^3$ and weight $W=0.28V$; hence, place line of indicator to 6.5 on R3 then set .5236 on "CI" of slide to indicator. Reading the volume V on scale "D" under the left index of "CI", it is found to be 144 cu. in. Next, move the indicator over 0.28 on "C" and read the weight W=40.4 lb. on "D". By the old method, set indicator to 6.5 on "D", set 6.5 on "CI" to indicator, set indicator to left index of "C" set 6.5 on "CI" to indicator, set indicator to left index of "C", then set .5236 on "CI" to indicator when the volume V can be read on "D" under the left index of "C". Resetting the indicator to 0.28 on "C" gives the weight W on scale "D" under the hair line.

Examples of cube roots with scales R1, R2, R3 and "D"

Rule 2.—Add 0, 1 or 2 to the characteristic of the given number so as to make it exactly divisible by 3. The quotient after dividing by 3 is the characteristic of the cube root. If nothing is added; or, in other words, if it is exactly divisible by 3, use scale R3; if 1 is added, use R2; and if 2 is added, use R1.

Let $A^{1/3}=x$

Top scale R1	Intermediate scale R2	Lower scale R3
$Nx=(Na+2)/3$	$Nx=(Na+1)/3$	$Nx=Na/3$

5. $(2.125)^{1/3}=1.286$	$N=(1+2)/3=1$	Use scale R1.
6. $(40,600)^{1/3}=34.40$	$N=(5+1)/3=2$	Use scale R2.
7. $(.000321)^{1/3}=.0685$	$N=(-3+0)/3=-1$	Use scale R3.
8. $\left(\frac{1}{50,200}\right)^{1/3}=.0271$	$R=1-5=-4$, $N=(-4+1)/3=-1$	Use R2.
9. $(605\times7.15)^{1/3}=16.3$	$R=3+1=4$, $N=(4+2)/3=2$	Use R1.

Referring to problems 8 and 9, it will be observed that the result is obtained without resetting to another scale, as would be necessary with the old arrangement.

Comparing my new arrangement of scales for cubes and cube roots; R1, R2, R3 and "D" with the old arrangement of "K" and "D", it is clear that the former will give greater accuracy, since the scale lengths are three times those of the latter. Another very decided advantage that can be seen from Example 4 is that when the cube is obtained on the "D" scale, it can be multiplied or divided by other factors directly, and this procedure cannot be followed with the old arrangement of scales.

Referring to Example 4 it can be observed that with the new scales, the final result is obtained with two settings of the indicator and one setting of the slide; whereas, with the old, four settings of the indicator and three of the slide are required to accomplish an equal result.

For squares and square roots the scales Q1 and Q2 are related to the "D" scale, in a manner similar to that used for the cube and cube root scales. The same advantages are apparent, and a few examples should suffice to make their use clear.

Squares of numbers using scales Q1, Q2 and "D"

Rule 3.—If the given number is read on Q1, the characteristic of its square read on "D" is 2 times that of the number less 1; and if on Q2, it is 2 times that of the number.

Let $A^2=x$

Scale Q1	Scale Q2
$Nx=2Na-1$	$Nx=2Na$

10. $(115)^2=13,200$	$N=(2\times3)-1=5$
11. $(.0095)^2=.00009$	$N=2(-2)=-4$
12. $(5.45\times10^{-5})^2=29.6\times10^{-10}$	$N=2(1-5)=-8$

13. Find area of circle 4½ in. diameter. The area $A=\pi/4\times D^2$

hence, set line of indicator to 4.5 on Q2, then set special mark representing $\pi/4$ on the "CI" scale of slide to indicator and read the area 15.90 sq. in. on "D" opposite the left index of "CI".

Examples of square roots with scales Q1, Q2 and "D"

Rule 4.—If one added to the characteristic of a number makes it exactly divisible by 2, scale Q1 should be used, and the characteristic of the root is $(N+1)/2$; but if the characteristic is exactly divisible by 2, scale Q2 should be used and the characteristic of the root is N/2.

Let $A^{1/2}=x$

Scale Q1	Scale Q2	
$Nx=(Na+1)/2$	$Nx=Na/2$	
14. $(36,000)^{1/2}=190$	$N=(5+1)/2=3$	Use scale Q1.
15. $(.00915)^{1/2}=.0956$	$N=(-2)/2=-1$	Use scale Q2.
16. $(2.43\times10^6)^{1/2}=1,560$	$N=(7+1)/2=4$	Use scale Q1.

17. Find the diameter of a circle whose area (A(is 1800 sq. inches. Diameter

$$D=\frac{(A)^{\frac{1}{2}}}{(\pi/4)};$$

hence, set line of indicator to 1800 on "D", then set left index of "CI" to indicator, next reset indicator to $\pi/4$ mark on "CI", then the required diameter 47.9 inches can be read under the hair line on Q2.

With the indicator set to any given number N on scale Q1 or Q2, the following powers and roots can be read from the front working face scales of my improved slide rule, as shown in Figs. 1 and 5: on "D" read N^2, on "CI" read $1/N^2$, on "K" read N^6, on "A" read N^4 and on R1, R2 or R3 read $N^{2/3}$. It will be observed that expressions such as $1/N^2$, N^6, and N^4 cannot be obtained by direct reading on existing slide rules; furthermore, it is clear that by utilizing all the scales shown in Figs. 1 and 5 a large number of engineering problems can be solved with less settings and greater accuracy than with slide rules now in common use. Since it is obviously impossible to give examples of all the combinations possible, the following can be considered representative:

18. Find the moment of inertia of a solid steel shaft 6.5 inches in diameter. The moment of inertia $I=.049D^4$, hence set indicator to 6.5 on Q2, then place the left index of slide in alignment with the indicator. The indicator is next reset to .049 on "B", when the moment of inertia I can be read under the hair line on "A" and it is found to be 87.6 in.^{4}.

19. Find the diameter of a line shaft to transmit 600 horsepower at 400 revolutions per minute—

$$\text{given } D=\frac{(448\times H.P.)^{\frac{1}{2}}}{(R.P.M.)}.$$

Solution: Set 400 on "B" (left section) to 600 on "A" (left section) and align indicator with 448 on B (left section) when the diameter D=5.09 can be read under the hair line on Q2.

With the indicator set to any given number N on scales R1, R2, or R3, the following powers and roots can be read from the front working face, Figs. 1 and 5 of my improved slide rule: on "A" read N^6, on "K" read N^9, on "CI" read $1/N^3$, on "D" read N^3 and on Q1 or Q2 read $N^{3/2}$. It will be noted that expressions such as N^6, N^9, and $1/N^3$ cannot be obtained by direct reading on existing slide rules.

The following examples will illustrate the effectiveness of these scales in the solution of certain engineering equations.

20. The minimum diameter of a steamship shaft $S=[(C.P.D^2)/3f]^{1/3}$. Given C=12, P=115, D=18 and f=740, find S. Solution:

$$S=[(12\times 115\times (18)^2)/3\times 740]^{1/3},$$

hence set indicator to 18 on Q1 and bring left index of "C" to indicator. Place indicator over 12 on "C" and bring left index of "C" to indicator, then move indicator to 115 on "C", next bring 3 on "C" to indicator and as a final operation, move the indicator to 740 on "CI", when the required diameter 5.86 inches can be read on R3.

21. Span between bearings of a shaft is calculated from the equation $S=(CD^2)^{1/3}$ where S=the span in feet, C=a constant=216 and D=the diameter in inches. Given D=2½ inches, find S. $S=[216(2.5)^2]^{1/3}=11.05$ ft. Solution: set indicator to 2.5 on Q1, then bring 216 on "CI" in alignment with indicator. Next, move indicator to left index of "CI" when the required span S=11.05 feet can be read on R1.

22. Let $x=(a^3\times b^{1/2}\times c^{1/3})^{1/2}$.

Find x if a=25, b=375 and c=4.75.

$x=(25^3\times 375^{1/2}\times 4.75^{1/3})^{1/2}$, hence set indicator to 25 on R2 and bring left index of "B" to indicator. Place indicator over 375 on B (left section) and set left index of "K" to indicator. Next, move indicator to 4.75 on "K" (left section) and read the result x=713 on scale Q2.

In Fig. 2, reference is now made to the "markings" adjacent, and directly to the right of scales Q1′ and Q2′. The notation added here is a key to the characteristic, or decimal point location, when using scales Q1′ and Q2′ in conjunction with scales Q1 and Q2. "D", "CI", and °C. If the diameters are given in mils or thousandths of an inch, in accordance with the Brown and Sharpe system of wire gauges, reference to a table of these gauges shows clearly that sizes from No. 0000 to 10 inclusive have three digits, or a characteristic of 3; whereas, sizes from No. 11 to 30 inclusive have two digits or a characteristic 2, and sizes from No. 31 to 40 one digit with a characteristic of 1. To the left of scale "C" on slide I (Fig. 1) is the scale for resistance, marked ° C., that normally covers a temperature range from 0° C. to 50° C. For the calculation of resistances, any desired temperature within this range is set to a reference line marked R (resistance) situated immediately beneath the ° C. scale, and on the fixed bar J. Directly beneath, and in line with the R referred to above is the symbol

$$\overset{+}{6\longleftrightarrow 5},$$

which enables one to determine the resistance characteristic, definitely as follows: Wire diameters read on Q1 or Q2 have a characteristic as given at the extreme right of Q1′ and Q2′, (Fig. 2); corresponding squares or circular mils then being read on "D", following rules for the characteristic already given. Finally, from the constant 5 or 6, depending on whether or not the slide has to be reset to the left, in order to obtain a reading on the "CI" scale, the characteristic representing circular mils is deducted, to give the resistance characteristic. The following example will make all these points clear.

Examples illustrating resistance calculations

23. Find the resistance of 1000′ of No. 16 B. & S. gauge copper wire at 20° C. Solution: set 20° C. to line R and move hair-line Z over 16 on the Q2′ scale. The diameter 50.8 mils can now be read on Q2, since this size falls in the range 11–30, for which the characteristic is +2. Reading under the hair-line on "D", the diameter squared or circular mils is found to be 2580 since sND=2N or 2×2=4. The resistance per 1000′ is read on "CI" under the hair-line, and because the reading is obtained without resetting the slide to the left, Nr=5−4=1; hence the required resistance is approximately 4.0 ohms per 1000′.

24. Find resistance per 1000′ at 25° C.—wire size 250,000 circular mils. Solution: set 25° C. to line R and set indicator over 250,000 on "D", reading the required resistance of .042 ohm on "CI". Note that in this example Nr=5−6=−1.

25. Find resistance per 1000′ of a copper wire .250 in. diameter at 0° C. and 50° C. Solution: set 0° C. to R and indicator to 250 on Q1; reading the resistance R=0.153 ohm per 1000′ on "CI". Next move slide so that 50° C. is in alignment with R when the resistance R=0.185 ohm per 1000′ can be read on "CI".

26. Find resistance per 1000′ of a No. 10 wire at 50° C. Solution: set line Z to 10 on Q1′ and 50° C. to R. In this position no reading can be obtained on the "CI" scale, so place indicator over left index of "CI", then bring right index of "CI" to indicator, after which the indicator is reset to 10 on Q1′ and a reading of 1.12 ohms per 1000′ is obtained on "CI". Note that in this example Nr=6−5=1 as given.

Considering the trigonometric scales of Fig. 3, and more particularly the special "markings" to the extreme right thereof, as appearing more clearly in the enlarged view Fig. 7; it is now evident that the "0" and "+1" in line with the tangent scales T1 and T2 respectively, represents the characteristic for these scales, in accordance with the methods of calculation previously given. Likewise, the "−1" and "0" in line with sine scales S1 and S2 respectively represents their characteristic. The use of these trigonometric scales in conjunction with the new face scales of Fig. 1, Q1 and Q2, as well as R1, R2 and R3, is best shown by the following examples:—

27. Let $x=(A^2 \sin b)^{1/3}$. Find the value of x when A=7.60 and b=35° 30′ or

$$x=[(7.60^2 \sin 30^\circ\ 30')]^{1/3}.$$

Solution: set indicator to 7.60 on Q2 (Fig. 1) and bring right index of slide to indicator. Reset indicator to 35° 30′ on S2 (Fig. 3) and read the required value of x on R2 (Fig. 1) where it is found to be 3.225. For the characteristic, note that $(7.60)^2$=2×1=2 and the product of $(7.60)^2$ sin 35° 30′ is 2+0=2, also the cube root of $(7.60)^2$ sin 35° 30′ is (2+1)/3=1 as given, indicating that the result should be read on R2.

28. Let $x=(a^3 \sin b \cos c)^{1/2}$. Find x if a=1955, b=50° and c=87° 30′. Solution: set indicator to 1955 on R1 (Fig. 1) and bring right index of slide to indicator. Reset indicator to 50° on S2 (Fig. 3) and move right index of slide to indicator. Next, move indicator to 87° 30′ on CS1 and read x=15,800 on Q1 (Fig. 1). Characteristics are: (3×4)−2=10, 10+0−1=9, and for the square root (9+1)/2=5 read on the Q1 scale.

29. Let $x=(a \tan b)^{1/2}$. Find x if a=6 and b=78°. Solution: set indicator to 78° on T2 (Fig. 3) and bring right index of slide to indicator, then reset indicator to 6 on "C" reading the result on Q2 where x is found to be 5.313. Characteristics are: 1+1=2 and 2/2=1 as given, the result being read on scale Q2.

30. In a right triangle $c=(a^2+b^2)^{1/2}$. Find c if $a=3$ and $b=4$. Solution:

$$\tan A=a/b=3/4=.75.$$

Set indicator to .75 on "D" (Fig. 3) and read A=36° 52′ on T1. By trigonometry $c=a/\sin A$, hence set indicator to 3 on "D" and bring 36° 52′ on S2 to indicator when the value of C=3/sin 36° 52′=5 can be read on "D" under the right index of "C".

31. Find the secant of 80° 30′ on the "D" scale. By trigonometry sec $a=1/\cos a$; hence, set indicator to left index of "D" and bring 80° 30′ on CS2 to indicator. On "D" opposite the right index of "C" read sec 80° 30′=6.06.

32. Find the cosecant of 25° 30′ on the "D" scale. By trigonometry cosec $a=1/\sin a$; hence, set indicator to left index of "D" and bring 25° 30′ on S2 to indicator. On "D" opposite the right index of "C" read cosec 25° 30′=2.32.

33. Find the value of $(350 \sec 89° 10')^{1/2}$. Solution: set indicator to left index of "D" and bring 89° 10′ on CS1 to indicator. Reset indicator to 350 on "C" when $(350 \sec 89° 10')^{1/2}=155$ can be read on Q1.

Placing the sine and cosine scales on the slide permits the reading of all trigonometric functions on the standard "D" scale as shown by the examples, and this is obviously a very decided advantage for extended or lengthy calculations.

I claim:

1. In a slide rule, a standard logarithmic scale, an inverted logarithmic scale, a temperature scale and a reference line, the inverted logarithmic scale and temperature scale bearing a fixed relationship to each other and being movable relative to the standard scale and reference line, so arranged with respect to each other that wire sizes of a given material in circular mils on the standard logarithmic scale are in alignment with their respective resistances in ohms per 1000 feet on the inverted logarithmic scale for any given position of the temperature scale, so that the resistance of said wire per 1000 feet, for any circular mil area, and for any temperature can be read directly on the inverted logarithmic scale.

2. In a slide rule, having a fixed bar and a sliding bar, a standard logarithmic scale and reference line on the said fixed bar, a temperature scale and an inverted logarithmic scale that bear a fixed relationship to each other on the said sliding bar, so arranged with respect to each other that wire sizes of a given material in circular mils on the standard logarithmic scale are in alignment with their respective resistances in ohms per 1000 feet on the inverted logarithmic scale for any given position of the temperature scale, so that the resistance of said wire per 1000 feet, for any circular mil area, and for any temperature can be read directly on the inverted logarithmic scale.

3. In a slide rule, a twofold logarithmic scale, a standard logarithmic scale, an inverted logarithmic scale, a temperature scale and reference line, the inverted scale and temperature scale bearing a fixed relationship to each other and being movable relative to the twofold logarithmic scale, the standard logarithmic scale and the reference line, so arranged with respect to each other that the diameters of a wire of a given material in mils on the twofold logarithmic scale are in alignment with their respective resistances in ohms per 1000 feet on the inverted logarithmic scale for any given position of the temperature scale, so that the resistance of said wire per 1000 feet for any given diameter and for any temperature can be read directly on the inverted logarithmic scale.

4. In a slide rule, having a fixed bar and a sliding bar, a twofold logarithmic scale, a standard logarithmic scale, and reference line on the said fixed bar, a temperature scale for the given material and an inverted logarithmic scale that bear a fixed relationship to each other on the said sliding bar, so arranged with respect to each other that the diameters of wire of said given material in mils on the twofold logarithmic scale are in alignment with their respective resistances in ohms per 1000 feet on the inverted logarithmic scale for any given position of the temperature scale, so that the resistance of said wire per 1000 feet, for any given diameter and for any temperature can be read directly on the inverted logarithmic scale.

5. In a slide rule, a twofold scale of "wire gauge" sizes, a twofold logarithmic scale, a standard logarithmic scale, an inverted logarithmic scale, a temperature scale for a given material and a reference line, the inverted scale and temperature scale bearing a fixed relationship to each other and being movable relative to the twofold scale of "wire gauge" sizes, the twofold logarithmic scale, the standard logarithmic scale and the reference line, so arranged with respect to each other that the "wire gauge" sizes are in alignment with their respective resistances in ohms per 1000 feet on the inverted logarithmic scale, for any given position of the temperature scale, so that the resistance of wire of said given material per 1000 feet, for any given gauge number and for any temperature, can be read directly on the inverted logarithmic scale.

6. In a slide rule, having a fixed bar and a sliding bar, a twofold scale of "wire gauge" sizes, a twofold logarithmic scale, a standard logarithmic scale and reference line on the said fixed bar, a temperature scale for a given material, and an inverted logarithmic scale that bear a fixed relationship to each other on the said sliding bar, so arranged with respect to each other that the "wire gauge" sizes are in alignment with their respective resistances in ohms per 1000 feet on the inverted logarithmic scale, for any given position of the temperature scale, so that the resistance of wire, of said given material per 1000 feet, for any given gauge number and for any temperature can be read directly on the inverted scale.

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