SLIDE RULE OF CIRCULAR TYPE, SET FOR EQUATIONS

Filed June 9, 1965 2 Sheets-Sheet 1

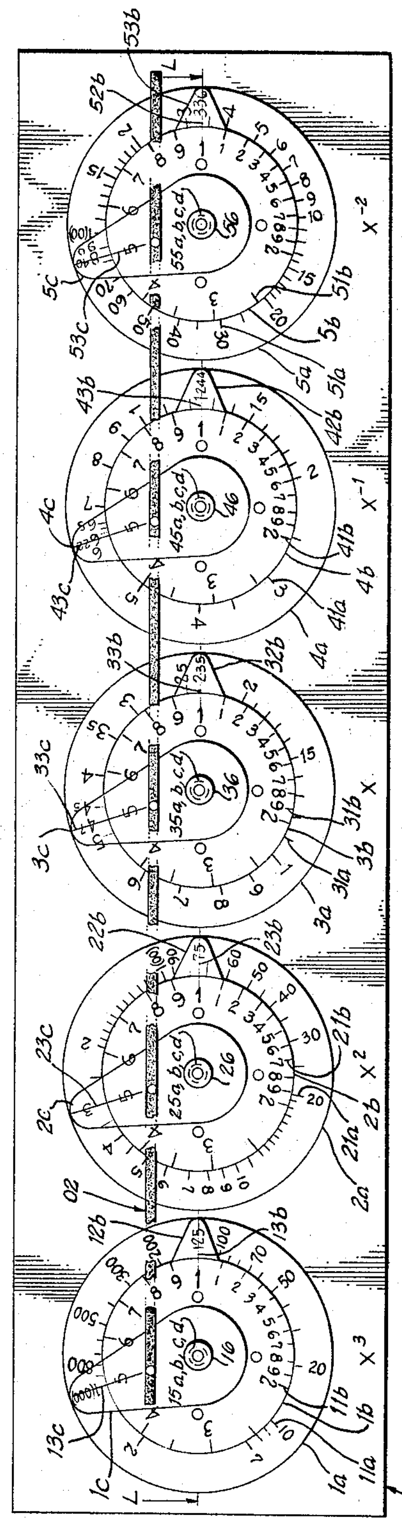

Fig. 1

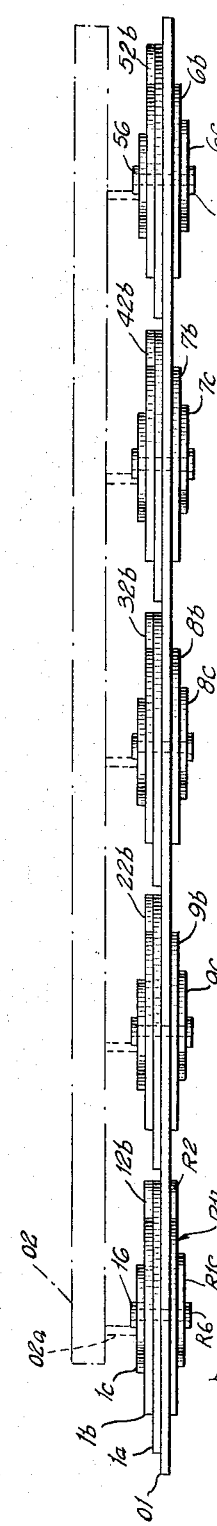

Fig. 3

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Nov. 29, 1966 — I. EZOPOV — 3,288,362

SLIDE RULE OF CIRCULAR TYPE, SET FOR EQUATIONS

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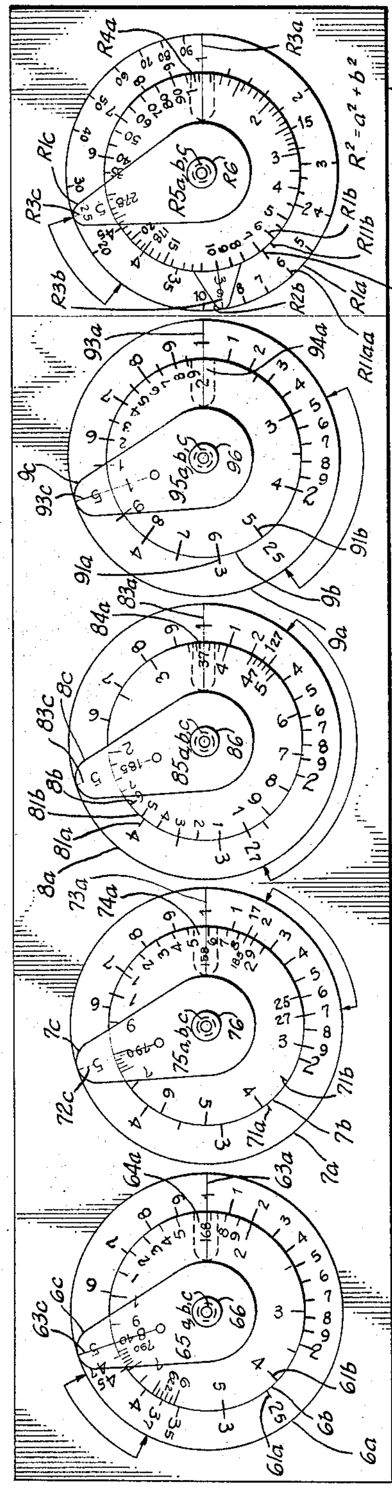

Fig. 2

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SLIDE RULE OF CIRCULAR TYPE, SET FOR EQUATIONS

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This invention relates to slide rules for performing mathematical functions to obtain a more accurate solution than what was previously possible in conventional slide rules, and more specifically is an improvement over slide rules of the type disclosed in the United States Patent No. 3,071,321.

At the present time, slide rules, either straight line or circular, can solve only simpler problems of quadratic and cubic equations, being not capable of solving polynomial equations in x of higher degree.

Accordingly, it is an object of this invention to provide a circular rule of simple construction that is accurate and can be used with facility for various polynomials in x, finding real and imaginary roots and solving given equations.

Another object of this invention is to provide a slide rule by means of which a given equation of higher degree can be transformed into another equation of lower degree, defining coefficient for every new term.

A further object of this invention is to provide a slide rule carrying out separate calculation for every term of equation on base of ordinary value of x for every term, while other values, as x^2 and x^3, for example, are obtained automatically on account of special combination of ordinary, square and cubic scales.

Still another object of this invention is to provide a slide rule for simultaneous observation of calculation for every term of equation for given root and for synchronous rotation of corresponding disks to avoid errors which can occur in rotation every disc separately.

Still further object of this invention is to provide a slide rule for solution equations of Pythagorian type known as $R^2=a^2+b^2$ and applicable in calculation of imaginary roots or sides of a right-angle triangle, even avoiding squaring of numerical values.

Still further object of this invention is to provide a slide rule which by way of practical proof contributes to mathematics as for example in analyzing of equations of 5 and higher degrees, in solution of equations for imaginary roots and in carrying out four basic mathematical operations on the same pair of logarithmic scales.

And still another object of this invention is to provide aforesaid slide rule which in addition of being accurate for solving equations, will be specifically adapted to utilize the advantages disclosed in the slide rule in Patent No. 3,071,321 of the same inventor.

These and other objects of the hereinbelow disclosed novel slide rule, will become apparent to those skilled in the art by referring to the following description taken together with the attached drawings. It is to be understood, however, that the drawings are for illustrative purposes only, and are not to be used as limiting the scope of this invention.

FIGURE 1 is a plan view of a circular slide rule, set for an equation that is construed in accordance with the invention;

FIGURE 2 is the backside view of the novel slide rule of FIGURE 1.

FIGURE 3 is an elevational view of the novel slide rule of FIGURE 1 and FIGURE 2.

To facilitate the description of the invention it will be noted that a limited number of scales are shown in the attached drawings and will be described. This limitation, however, should not be construed as defining a limitation of the invention, inasmuch as the number of sets and scales can be varied in accordance with the desired degree and type of equation.

Now referring to the drawings and specifically to the drawings FIGURE 1 and FIGURE 3, the novel slide rule as shown has five separate slide rules placed on the front side of plate **01**. Each of these slide rules, which will be referred to as sets **1**, **2**, **3**, **4** and **5**, are provided for calculation of corresponding term of given equation comprising values of x with different exponents: x^3, x^2, x, x^{-1} and x^{-2}, as shown on said plate **01**. Each set **1** . . . **5** of the novel slide rule is composed of three concentric discs, two of each "*a*" and "*b*" are for scales "*a*" and "*b*" and third "*c*" is provided mainly for aligning numbers on different scales and will be referred to as searcher disc "*c*." Every disc of a set together with plate **01** have aligned central openings **15***a*, *b*, *c*, *d*; **25***a*, *b*, *c*, *d*; **35***a*, *b*, *c*, *d*; **45***a*, *b*, *c*, *d*; and **55***a*, *b*, *c*, *d* and pivot-pins **16**, **26**, **36**, **46** and **56** respectively which fasten said sets together and to common plate **01** and permit the rotation of discs relative to each other.

The discs "*a*" and "*b*" (**1** . . . **5**) progressively decrease in diameter, and are provided with periferal logarithmic scales **11***a*, *b*, **21***a*, *b*, **31***a*, *b*, **41***a*, *b* and **51***a*, *b* respectively. Scales **11***a*, **21***a* and **31***a*, *b*, are provided for multiplication and disposed in opposition to each other, whereas scales **41***a* and *b* and scales **51***a* and *b* are provided for division and disposed in the same direction. Each disc **1***b*, **2***b*, **3***b*, **4***b* and **5***b* has reading tab **12***b*, **22***b*, **32***b*, **42***b* and **52***b* respectively with corresponding reference hairline **13***b*, **23***b*, **33***b*, **43***b* and **53***b* which will be referred to as reading tabs.

The discs "*c*" have searcher tabs **12***c*, **22***c*, **32***c*, **42***c* and **52***c* with reference hairlines **12***c*, **23***c*, **33***c*, **43***c* and **53***c* respectively. Tabs "*c*" and "*b*" are transparent for reading numbers on scales "*a*" and "*b*." Each of discs "*c*" (**1** . . . **5**) is provided with a hole in radial direction of hairlines **13***c*, **23***c*, **33***c*, **43***c* and **53***c* respectively located on the same distance from corresponding centers. They are provided for synchronous rotation of all discs "*c*" (**1** . . . **5**) by means of a common bar **02** with five axes **02***a* located on the same distance one from other as corresponding holes in discs "*c*." Similarly discs "*b*" (**1** . . . **5**) have three holes each for synchronous rotation discs "*b*" by one other bar (not shown) similar to bar **02** for, selecting such a group of holes which will not interfere with operation of bar **02**.

Referring now to the drawings, FIGURES 2 and 3, the novel slide has other five separate slide rules, which will be referred to as sets **6**, **7**, **8**, **9** and R placed on back side of common plate **01**. Sets **6** . . . **9** each have two discs "*a*" and "*b*" with logarithmic scales **61***a*, *b*; **71***a*, *b*; **81***a*, *b* and **91***a*, *b* respectively. Discs "*a*" are not real movable discs but drawn pictures on plate **01** together with scales **61***a*, **71***a*, **81***a* and **91***a*, reference lines **63***a*, **73***a*, **83***a* and **93***a* and corresponding reference boxes **64***a*, **74***a*, **84***a* and **94***a*, which can be seen only through transparent disc "*b*" and searcher tabs "*c*." Searcher discs **6***c*, **7***c*, **8***c* and **9***c* have reference hairlines **63***c*, **73***c*, **83***c* and **93***c* respectively. Each of discs "*c*" is provided with a hole in radial direction of hairline "*c*" for their synchronous rotation by means of bar **02**, using only 4 axes, or by a similar bar. All discs of a set (**7** . . . **9**) have aligned central openings **65***a*, *b*, *c*; **75***a*, *b*, *c*; **85***a*, *b*, *c* and **95***a*, *b*, *c* and pivot-pins **66**, **76**, **86**, and **96** respectively. Openings **65***c*, **75***c*, **85***c* and **95***c* coincide with plate openings **55***d*, **45***d*, **35***d* and **25***d* respectively, while pivot-pins **66**, **76**, **86** and **96** are continuations of pivot-pins **56**, **46**, **36** and **26** respectively, as shown.

Two arrows at each set **6**, **7**, **8** and **9** relate to one factor and sum of addition as it is explained by way of an example for every set and can be found in continuation of this description.

Set R, which is provided to carry out equation of type $R^2=a^2+b^2$ known as Pythagorian equation, has one non-movable disc R1*a* with ordinary scale R11*a*, square scale R11*aa*, hairline R3*a*, reference box R4*a*, all drawn on back side of plate **01** and two real discs R1*b* and R1*c*. Disk R1*b* has square logarithmic scale and tab R2*b* with reference hairline R3*b* at index 10 of scale R11*b*. Disc R1*c* is provided with reference line R3*c* and will be referred to as searcher disc. All discs R1*a*, R1*b* and R1*c* have aligned central openings R5*a*, *b*, *c* and pivot-pin R6. Opening R5*a* coincides with opening **15*d*** of plate **01**, while pivot-pin R6 is the continuation of pivot-pin **16**. Two arrows shown at set R relate to one factor and sum of addition as it is explained in continuation by means of an example.

Referring again to the drawing FIGURE 1 with logarithmic scales **11*a*** . . . **51*a*** and **11*b*** . . . **51*b***, the novel slide rule is used for solution of polynomial equation in *x*. To solve for example an equation of fifth degree by means of five pairs of scales "*a*" and "*b*" as shown, consider equation:

$$x^5-3x^4-47x^3+27x^2+622x+840=0$$

This equation as known is a particular case of a general equation of fifth degree which can be expressed as:

$$x^5+p_5x^4+s_5x^3+t_5x^2+u_5x+q_5=0$$

where $-p_5$ is the sum of five roots x_1, x_2, x_3, x_4 and x_5 which equals +3, q_5 is the product of the same roots and equals 840, while s_5, t_5 and u_5 are coefficients which equal −47, +27 and +622 respectively as given in the particular equation.

Before proceeding to the work with the novel slide rule it will be of certain use to divide both sides of given equation by x^2 getting new form of equation with diminished values of *x* and rearranged as follows:

$$x^3-3x^2-47x+622/x+840/x^2=-27$$

or generally:

$$x^3+p_5x^2+s_5x+u_5/x+q_5/x^2=-t_5$$

To start working on the novel slide rule certain value of *x* has to be chosen, no matter which one. If so chosen value is wrong, then the sum of all terms of the given equation will not be equal −27 as given. Consider now solution of the equation with $x=5$, which will be referred to as root x_5. Align, by hand or by a bar similar to bar **02**, all hairlines **13*b***, **23*b***, **33*b***, **43*b*** and **53*b*** in corresponding tabs "*b*" of discs **1*b***, **2*b***, **3*b***, **4*b*** and **5*b*** with middle line LL of plate **01**. Then, holding all discs "*b*" in the obtained position by hand or by said bar to prevent their rotation, align by hand or by bar **02** all hairlines **13*c***, **23*c***, **33*c***, **43*c*** and **53*c*** of searcher discs **1*c***, **2*c***, **3*c***, **4*c*** and **5*c*** with numbers 5 of corresponding scales **11*b*** . . . **51*b***. In next step rotate one by one discs "*a*" to put in alignment coefficient of every term with 5 of corresponding disc "*b*," still holding all 5 discs in the same position by said bar as shown. A term such as x^3 is said to have coefficient 1. So align now index 1 of scale **11*a*** with 5 of scale **11*b***, number 3 of scale **21*a*** with 5 of scale **21*b*** number 47 of scale **31*a*** with 5 of scale **31*b***, number 622 of scale **41*a*** with 5 of scale **41*b*** and number 840 of scale **51*a*** with 5 of scale **51*b***. All results now appear in reading tabs "*b*" on line LL. It is understood to be known how to read place-value of every result on ordinary, square and cubic scales. Supply shown results with plus and minus signs taking them for positive root $x_5=5$ directly from the equation. It will be:

$$125-75-235+124.4+33.6=-27$$

The equality of the left-hand and right-hand sides of the equation is a proof that root $x_5=5$ satisfies given equation.

As described each one of the five roots of the given equation can be found. To do it easier and more quickly keep every "*a*" disc from moving, fastening them to plate in shown position, for example by means of paperclips (not shown). Then proceed as follows. Rotate all five discs **1*b*** . . . **5*b*** simultaneously using one bar for their rotation and hold all five searcher discs **1*c*** . . . **5*c*** in shown position by means of bar **02**. Then number 5 of scales "*b*" will be changed on one other but the same number on scales "*b*." The set of scales "*b*" by means of hairlines "*c*" will be shown in alignment with the same given coefficients as it is shown on scales "*a*" for number 5. The reading tabs **12*b*** . . . **52*b*** will be all shifted on the same angle from middle line LL of plate **01** showing new results for every term of the equation. The user of the novel slide rule will learn very soon to quickly add the last digits as soon as possible to get −7 the last digit of given −27. Then the user will realize also that the difference between both sides of one equation will first increase slowly then decrease slowly until it becomes 0 and new root discovered. If said difference increases fast, no root to be expected. Some of roots will negative, in which case plus and minus signs will be changed only at terms having odd exponents as for example at terms *x* and x^3. In such a case the sequence of shown signs will be −, −, +, −, +. The roots x_4, x_3, x_2 and x_1 which are +7, −4, −3 and −2 (not shown) can be easily demonstrated on in a similar manner as root $x_5=5$.

In some cases the obtained result is not precise enough and has to be rechecked on some other way. This is also provided at novel slide rule.

Referring now to the drawings FIGURE 2 and FIGURE 3, the root $x_5=5$ will be checked at given equation of fifth degree

$$x^5-3x^4-47x^3+27x^2+622x+840=0$$

The checking will be performed by elimination root 5 from every term of given equation, getting a new equation of fourth degree as shown. The procedure is the following. Align reference hairlines **63*c***, **73*c***, **83*c*** and **93*c*** of searcher discs **6*c***, **7*c***, **8*c*** and **9*c*** with corresponding numbers 5 of scales **61*a***, **71*a***, **81*a*** and **91*a*** respectively using bar **02** or alike for synchronous rotation of said four discs "*c*." Hold discs "*c*" in obtained position by means of the same bar and rotate now one by one discs "*b*." Align 840 of scale **61*b*** with 5 of scale **61*a***. Read the quotient of division 840/5 on line **63*a*** in box **64*a***, which is 168, as shown. Add now next coefficient 622 to 168 which equals 790. This addition is also shown on logarithmic scales **61*a*** and **61*b***. The distance between numbers 168 and 622 in logarithmic units amounts 3.7 (scale **61*a***) in alignment with 622 of scale **61*b*** (see arrow). Add +1 to 3.7 getting 4.7. Read opposite to 4.7 of scale **61*a*** the sum 790 on scale **61*b*** (see other arrow).

Now align number 5 of scale **71*a*** with number 790 of scale **71*b***, rotating scale **71*b***, and holding discs "*c*" in obtained position. Read the quotient of division 790/5 on line **73*a***, box **64*a***. It amounts to 158 as shown. Add next coefficient 27 to 158 what equals 185. Show this addition on scales **71*a*** and **71*b***, defining distance between 158 and 270 (caution, it is not 27) of scale **71*b*** with logarithmic units of scale **71*b***. It amounts approximately 1.7 at 270 (see arrow). Diminish ten times this amount for addition of 158 and 27 getting .17. Add now +1 to .17 getting 1.17. Read opposite to 1.17 of scale **71*a*** the sum 185 on scale **71*b*** (see corresponding arrow).

Now align number 185 of scale **81*b*** with number 5 of scale **81*a***, moving scale "*b*" and holding scale "*c*" in shown position. Read the division of 185/5 as 37 of scale **81*b*** aligned with line **83*a***, box **84*a***. Add next coefficient −47 of given equation to 37. Get −10. Show this addition (subtraction) on scales **81**a and **81**b defining distance between 37 and 47 (caution, it is not —47) of scale **81**b in logarithmic units of scale **81**a. Get 1.27. Having difference instead of a sum subtract 1 from 1.27 obtaining .27. Multiply .27 times 10 which equals 2.7. Read opposite to 2.7 of scale **81**a the difference 10 of scale **81**a (see corresponding arrows for 2.7 and 1.27).

Now align number 10 (it is 10) of scale **91**b with number 5 of scale **91**a, moving scale "b" and holding scale "c" in obtained position. Read the division of $-10/5$ as -2 (shown 2) on line **93**a, box **94**a. Add next coefficient -3 to -2. Get -5. Show this addition on scales **91**a and **91**b defining distance between -2 and -3 (scale **91**b) as 1.5 in logarithmic units (scale **91**a). Add plus 1 to 1.5 obtaining 2.5. Read in opposition to 2.5 of scale **91**a the sum 10 as -10 for negative numbers (see arrows at 1.5 and 2.5). This satisfies the equation, because $-5/5$ is -1 what with next coefficient $+1$ make 0. The root x_5 on this way is eliminated, creating new equation of fourth degree with new coefficients for every term of equation as shown on lines **61**a, **71**a, **81**a and **91**a, so the new equation is:

$$x^4+2x^3-37x^2-158x-168=0$$

It is properly to be noted that every coefficient (numercial value) changed its sign from what was shown at checking of the equation. In general terms this equation is:

$$x^4+p_4x^3+s_4x^2+t_4x+s=0$$

The root x_4 can be found from this equation and then eliminated from it getting new cubic equation of general form:

$$x^3+p_3x^2+s_3x+q_3=0$$

The root x_3 can be found from the obtained cubic equation, which again can be transformed in new square equation:

$$x^2+p_2x+q_2=0$$

It is apparent, that performing of the equation of diminished degree on the novel slide rule demands less and less sets to be engaged, dealing in the same time with smaller numbers. How simple it can be for a square equation, consider a problem to find roots x_1 and x_2, having equation:

$$x^2+52x+235=0$$

Referring now to the drawing FIGURE 1 set x, put reference line **33**b in alignment with number 235 of scale **31**a. Move now searcher disc **3**c back and forth until by means of reference hairline **33**c two opposite numbers are found, whose sum is 52. Those numbers are 47 and 5 as shown. Having positive term x and positive constant term 235 roots x_1 and x_2 will be negative as known.

Referring now again to the drawings FIGURES 2 and 3, consider a problem to solve an equation, having imaginary roots, as shown on scales **R11**a (**R11**aa) and **R11**b:

$$x^2-6x+25=0$$

This equation may be both independent and the rest of an equation of a higher degree after other real roots are found. No real roots can be found for this equation, but the rule, that $-p$ is the sum of roots x_1 and x_2 and q is the product of x_1 and x_2 will be applied now to the complex roots known as $a+bi$ and $a-bi$. Their sum is $2a$, their product is as known

$$(a+bi)\ (a-bi)=a^2+b^2$$

This is expressed on the drawing FIGURE 2 as

$$R^2=a^2+b^2$$

where R has the same meaning as product q. So $2a=6$, $a=3$ and $R^2=25$ as given. To find now value of b put 3 of scale **R11**a in alignment with reference hairline **R3**b in tab **R2**b, rotating disc **R1**b because disc **R1**a is drawn on plate **01**. Put 25(R^2) of scale **R11**aa, which equals 5(R) on scale **R11**a, in alignment with reference hairline **R3**c of disc **R1**c. Read now distance between 3 and 5 of scale **R11**a in logarithmic units as 27.8. Subtract 10 from 27.8, obtaining 17.8. Opposite to 17.8 read 4 on scale **R11**b, which is b. Now complex roots are known, they are $3+4i$ and $3-4i$. Their sum is $-p_1=3+4i+3-4i=6$, their product

$$q_1=(3+4i)\ (3-4i)=25$$

Set R can be used for rectangle and triangle, as well, finding out one side if two others are known (squaring will be avoided). In the same time other calculations are shown on the same scales **R11**a and **R11**b. For example, division of 10 by 3^2 (see reference hairline **R3**b) or division of 27.8 by 5^2 (see reference hairline **R3**c) is 1.11 as shown on scale **R11**b in alignment with line **R3**a in box **R4**a. Some other calculations can also be shown on other sets, particularly on sets x^3 and x^2 what only makes the novel slide rule more attractive.

Having thus described my invention, I claim:

1. A slide rule calculator comprising a plurality of circular slide rules mounted on a common base, wherein the axis of each said slide rule, falls on a straight line, and wherein each slide rule comprises a plurality of circular discs of decreasing diameter mounted on a common axis, the largest disc being mounted closest to the base, with the discs of smaller diameter superimposed concentrically thereover, each slide rule including a searcher tab mounted over the said discs, and about the same axis wherein said tab is provided with a hairline for aligning predetermined portions of the concentric discs, each of said discs being provided with logarithmic scales, and wherein at least one scale on one of the said slide rules, has a logarithmic scale in a reverse direction than on the other slide rules, one of said discs including an index tab with a hairline to align the said disc with a specific predetermined portion of the scale on the adjoining concentric disc in combination with means joining the searcher tab on all the slide rules, so that all searcher tabs can be set simultaneously upon the setting of one of the searcher tabs, thereby coordinating the functioning of all the slide rules into one calculating unit facilitating the necessary computations to ascertain the roots of equations of varying degrees.

2. A slide rule calculator as in claim **1**, wherein the said means comprises holes provided in the searcher tabs along a radial line equidistant from the centers of the axis of each of the slide rules, in combination with a rod having a plurality of pegs adapted to be inserted into each of said holes, whereby movement of any one of the searcher tabs will cause all of the searcher tabs to be moved simultaneously, due to the rod, and furthermore permitting the searcher tabs to move rotatably with respect to the said pegs.

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