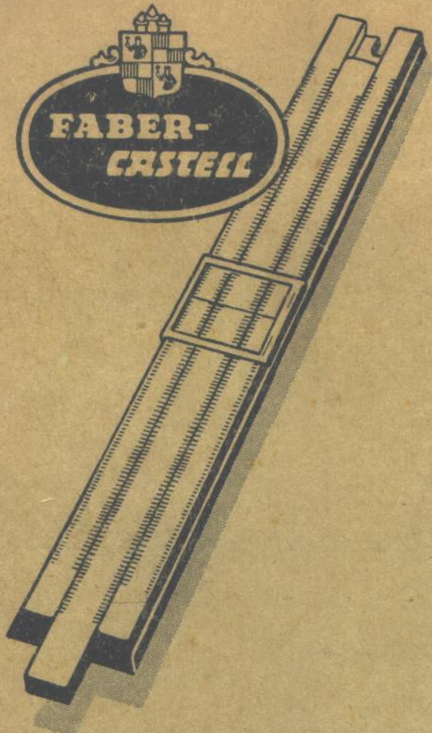


INSTRUCTIONS

for CASTELL ADDIATOR Slide Rule

1/87 A System Rietz
for Mechanical and Constructional Engineers

for multiplication
division
addition
subtraction

A. W. FABER-CASTELL, STEIN NEAR NUREMBERG

MAXIMATOR EXTENSION SCALE

This scale is intended for quick and accurate calculations by the logarithmic method. By its use logarithms of numbers can be read quickly to the 4^{th} or 5^{th} place, thus avoiding long and tiresome references to logarithm tables and interpolated figures.

The scale is read upwards from the bottom to the top, the green portion giving the mantissa corresponding to the number itself on the white portion.

Any figures may be multiplied together by reading off their respective logarithms from the green scale opposite to their values on the white scale, and adding the logarithms together on the Addiator on the back of the slide rule.
The resultant is the log of the desired answer, of which the value can be read off on the white scale against the resultant log on the green scale.

Division is done by subtracting the log of the divisor from the log of numerator and reconverting the resultant log in the same way. In this process no notice is to be taken of negative results as the right mantissa always shows up automatically in the round openings in the centre scale of the Addiator.

Example:

$$\boxed{4738} + \boxed{4144} \qquad \boxed{7908}$$

$$\frac{29{,}775 \times 2{,}5965}{12{,}513} = 6{,}178$$

$$-\boxed{0974}$$

The framed figures are the mantissa corresponding to the numbers of the example.

CASTELL-Addiator

Slide Rule 1/87 A System Rietz

FABER-CASTELL

CASTELL Precision Slide Rules

are the result of many years experience, a culmination of the skilled workmanship of men with long training; the rules are unsurpassed for precision and

CASTELL PRECISION Calculating Rules with celluloid facings

embody in their construction metal strips inserted in the stock and the slide which ensure the rule maintaining its true position. Moreover should the rule become warped by some unusual cause, these metal inserts permit pressure to be applied to the rule thus ensuring that the stock and slide be returned to their original position of complete agreement.

Furthermore in order to ensure the slide is held firmly, yet still permitting the even movement so essential for rapid and accurate calculation with the rule, A. W. Faber-Castell Precision Calculating Slide Rules are fitted with a lateral Steel Spring Base.

Steel Base Patent Nr. 10 713

The base of the rule is constructed in two parts, the stock being united by the lateral steel spring plates which have the effect of gripping the slide evenly throughout its length.

This arrangement reduces the possibility of any warpage due to atmospheric or temperature changes and under normal working conditions ensures a most satisfactory working of the slide rule.

All celluloid scales on the rule have mathematically exact engraved hair line divisions.

Treatment of Slide Rules

Slide rules should be kept in a dry, but not warm, place and particular attention should be paid to the necessity of keeping them away from dampness and the sun's rays.

When used in a very damp atmosphere it may be advisable to apply very small particles of vaseline or paraffin wax to the slide and its guides. If the lubricants are applied sparingly the treatment can be repeated from time to time but over-greasing must be avoided at all costs as this will merely tend to clog the slide in the stock.

Slide Rules that have become soiled with constant handling should be cleaned with a soft rag lightly moistened with petrol. Any spirits which dissolve celluloid should be avoided.

Instructions

A brief yet basically adequate instruction booklet is supplied free with every rule when sold.

A.W. FABER - CASTELL, STEIN near Nuremberg

London Agency: BERRICK BROS. LIMITED 17, Bury Street, LONDON, E. C. 3.

Instructions for the Use of the Regular Scales

Introduction

With the aid of the Calculating Rule, multiplication and division can be effected with a sufficient degree of accuracy for most cases occuring in practice, while various other, and frequently rather complicated calculations, can be made quickly and with certainty. In addition, an entire series of algebraic, trigonometric and technical calculations can be carried out with the aid of the instrument, so that the Calculating Rule has now become indispensable to the student, engineer and the practical man.

The following brief instructions only indicate the fundamental calculations which can be carried out with the Calculating Rule. For special study **the guide issued in book form** is recommended; this contains **numerous examples, with figures,** furnishing an excellent introduction to the practical application of the Calculating Rule.

Definitions

In the following instructions, the several parts of the Calculating Rule will be briefly referred to as follows: — The two parts firmly connected with each other are the "rule"; the part movable in the rule is the "slide", and the sliding perspex plate with a line across it, is the "cursor". —

For convenience, the scales are described by different letters.

The main scales are called **A, B, C** and **D.**

The back of the rule body is cut away at each end to expose a portion of the slide and on the edge of this slot a special line is marked. This is the index line for use with scales, **S, S-T, T** and **L.** The left-hand end of the slide on rules 1/98, 4/98 and 67/98 is fitted with two short pointers for reading scales **W** and **V.**

The scales of the calculating rule represent the logarithms of numbers from 1 to 10 (**Cr, C** and **D**), from 1 to 100 (**A** and **B**), from 1 to 1,000 (**Cu**), also the trigonometrical functions, sine (**S** and **S-T**) to 90°, tangents (**T** and **S-T**) to 45°, as lengths. An evenly divided scale (**L**) permits the reading of logarithms and antilogarithms.

The reciprocal scale (**Cr**) corresponds to scales **C** and **D**, but is arranged along the middle of the slide and runs from right to left.

A portion of the log-log scale (**LU**) is placed on the upper edge of the rule face, the continuation (**LL**) being on the lower edge.

The **W** and **V** scales are along the centre of the rule under the slide., These are special scales used in electrical calculations and only found on certain models.

Multiplication and division can be carried out on the upper scales (**A** and **B**), as well as on the lower scales (**C** and **D**). On the upper scales the distance from 1 to 10 is equal to that from 10 to 100, and the entire length from 1 to 100 is equal to the length from 1 to 10 on the lower scales. Consequently, the accuracy of the reading is greater by one decimal place on the lower scales than on the upper ones. The **A** and **B** scales should be used chiefly where great accuracy is not important, or for combined multiplication and division.

In order that there should be no misunderstanding of the settings, the different portions of the scales are shown in the following figure.

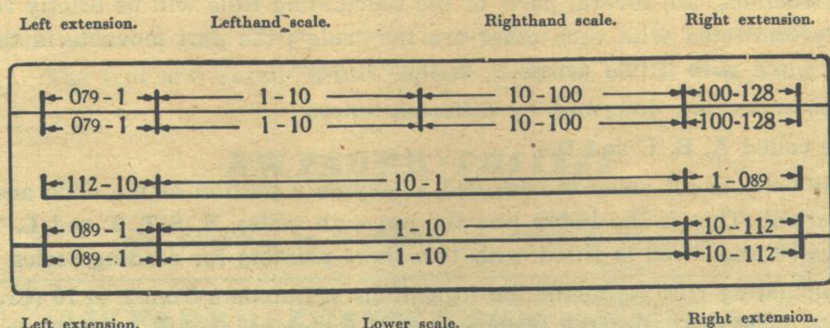


Fig. 1

A setting could be made on the **A** or **B** scales, for instance, at 0·89 on the left-hand extension, 8·95 on the left-hand scale, 89·5 on the right-hand scale, or 111·2 on the right-hand extension. No matter is used, it has no bearing on the decimal point. The settings on the lower scales are made in a similar manner.

Number of Places in Result

In nearly all cases the number of figures in the result will be known beforehand and consequently only the numerical values come into question in these cases.

Multiplication

> **Two numbers are multiplied together by adding the distances corresponding to the numbers on the rule and slide.**

E x a m p l e, Fig. 2: 6×3·5 = 21

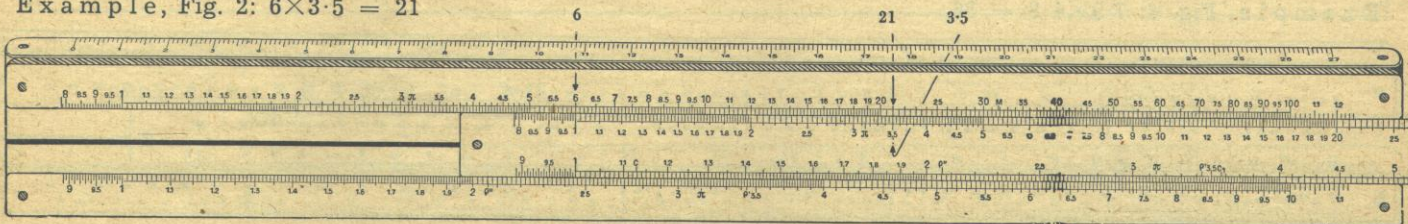


Fig. 2

Set 1 on scale **B** under 6 on scale **A,** place the cursor line over 3·5 on scale **B**, and read the product, 21, on scale **A** under the cursor line.

The following example can be worked in the same manner on the lower scales.

Example, Fig. 3: 2·5×3 = 7·5.

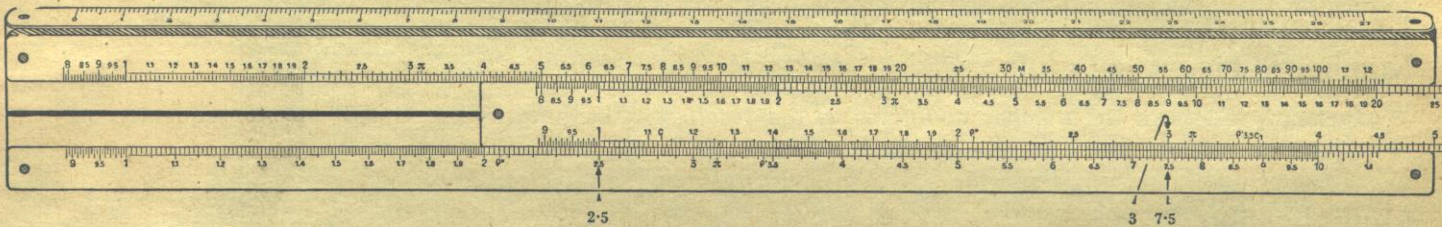


Fig. 3

Working on the lower scales it will be found that sometimes the second factor in multiplication problems falls beyond the end of the rule. In this case set **C** 10 over the first factor, draw the cursor line to the second and read the result under the cursor line.

Example, Fig. 4: 7·5×4·8 = 36.

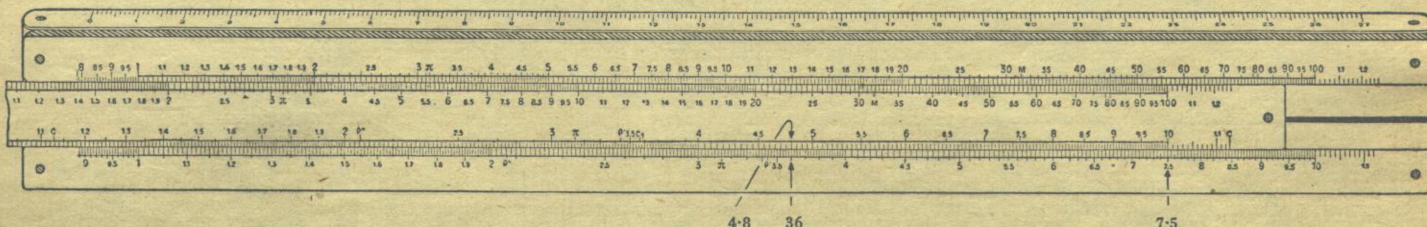


Fig. 4

As will be evident from these examples. it is immaterial whether the setting is made with the right or the left end of the slide. It also follows from these examples that continued multiplication, that is so say, when more than two factors are involved, can be carried out very easily, as the intermediate results need not be read off. It is only necessary to set the cursor to the second factor as before and to bring one end of the slide under the cursor, when the multiplication by the third factor can at once be made and read off, or further multiplications made.

As already referred to, most rules have their scales extended beyond the index figures at both ends. This has the advantage that any values which are just beyond the range of the scales may be set without changing indices.

Division

Division is carried out by subtracting the length corresponding to the divisor from the length corresponding to the dividend.

Examples, Fig. 5: 1. 210 ÷ 35 = 6
2. 7·35 ÷ 3 = 2·45

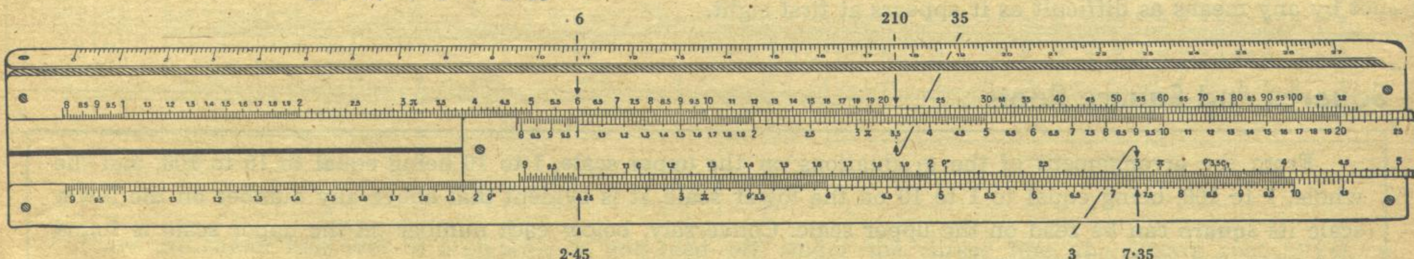


Fig. 5

1) Bring the divisor, 35, on scale **B,** under the dividend 210 on scale **A,** and read the quotient, 6, on scale **A** above 1 on **B.**

2) Bring the divisor, 3, on the lower slide scale, above the dividend, 7·35 on the lower rule scale **D**, and read the quotient, 2·45, on scale **D** under 1 on **C.**

Compound calculations, that is to say, multiplications and divisions in immediate sequence can easily be made with the Calculating Rule. The intermediate results need not be read off if it is not necessary to know them, and, after the last setting, the correct final result will appear. It is best to begin such calculations with a division, then follow with a multiplication, then another division and again a multiplication and so on.

Reading the Scales

Practice is required in order to calculate quickly and with certainty by means of the Calculating Rule. The values of the engraved graduation on the various scales must become impressed on the mind, more particularly those that are not marked with numbers. The estimation of all those numerical values which are not marked on the rule, must be practised, that is to say, the value of the spaces between adjacent graduations must be learnt. With some practice the requisite accuracy will be obtained, and it will be found that this estimating is not by any means as difficult as it appears at first sight.

Squares and Square Roots

From the arrangement of the graduations on the upper scale, 1 to 10 being equal to 10 to 100, and the whole, 1 to 100, being equal to 1 to 10 on the lower scale, it is evident that above any number on the lower scale its **square** can be read on the upper scale. Conversely, below each number on the upper scale is found its **square root** on the lower scale.

Example, Fig. 6: $3^2 = 9$.

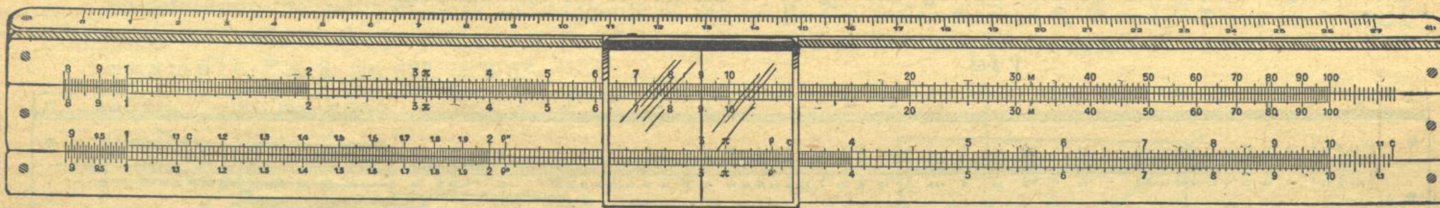


Fig. 6

Place the cursor line over 3 on scale **D**, and under the line read the square (9) on scale **A**.

Example, Fig. 7: $\sqrt{36 \cdot 5} = 6 \cdot 04$.

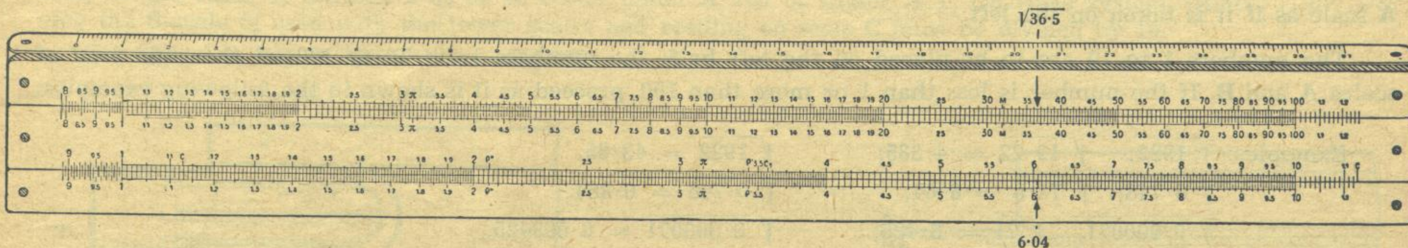


Fig. 7

Place the cursor line over 36·5 on scale **A**, and read off, under the cursor line, the square root (6·04) on scale **D**.

The significant figures 3·65 on the left-hand **A** scale cannot be used in this case. The value on **D** under this is $\sqrt{3{\cdot}65} = 1{\cdot}91$, the number having one figure to the left of the decimal point.

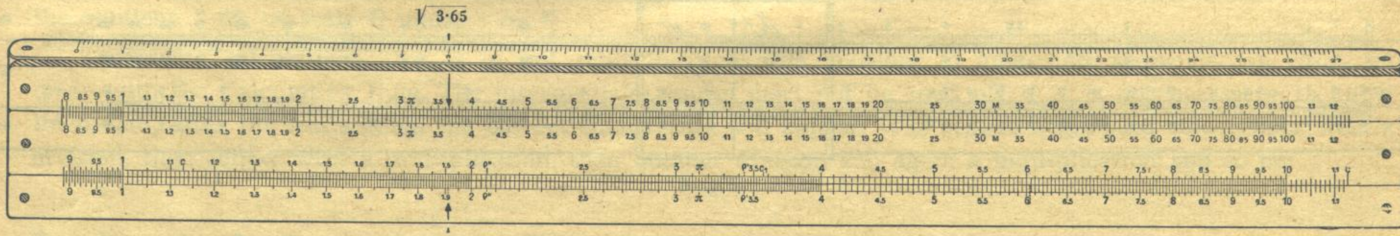


Fig. 7a

Therefore, in extracting a square root the result will not be the same if the number is set on the right-hand **A** scale as if it is taken on the left.

The numbers 1 to 10 are to be placed on the left half; the numbers from 10 to 100 on the right half of scales **A** and **B.** If the number is less than 1 or more than 100, proceed as it is shown in the following examples:

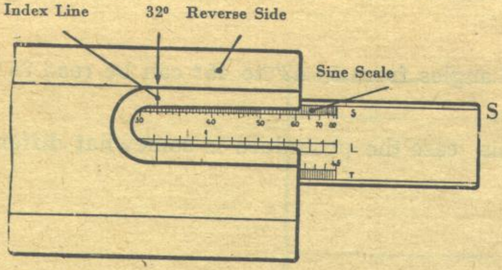
Examples: $\sqrt{1922}$; $\sqrt{19{\cdot}22} = 4{\cdot}385$; $\sqrt{1922} = 43{\cdot}85$.
$\sqrt{0{\cdot}746}$; $\sqrt{74{\cdot}6} = 8{\cdot}64$; $\sqrt{0{\cdot}746} = 0{\cdot}864$.
$\sqrt{0{\cdot}000071}$; $\sqrt{71} = 8{\cdot}425$; $\sqrt{0{\cdot}000071} = 0{\cdot}008425$.

It is necessary to see that the correct section of the **A** scale is used for setting the number. When it contains an odd number of figures before the decimal point, the number is taken on the left-hand **A** scale, if an even number of figures appear before the decimal point the number is found on the right-hand **A** scale.

Sines and Tangents

To determine the value of sines and tangents of any angle the scales marked **S**, **T** and **S-T** are used. These scales are read against the index lines in the slots at either end of the back of the rule.

E x a m p l e, Fig. 8: sin 32° = 0·53.



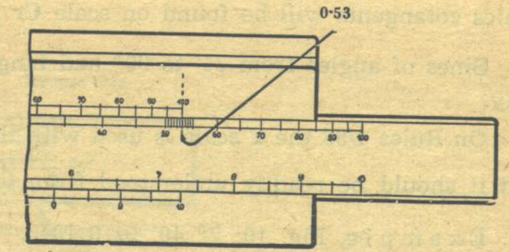
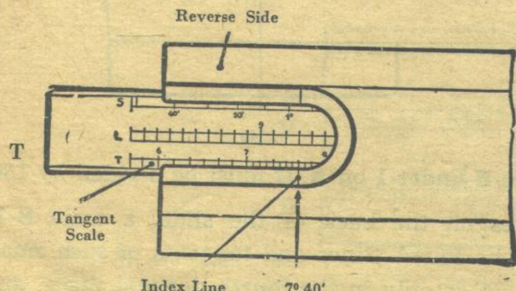


Fig. 8

Set the angle 32° on the **S**-scale either under the right-hand or the left hand upper index in the slots, and read off the value of the sine 0·53 on **B**, either under **A** 100 or under **A** 1. On rules system "Rietz" (1/87, 4/87 etc.) the **S**-scale is used with the lower scales and reading on scale **C** must be divided by 10.

E x a m p l e , Fig. 9: tan 7° 40' = 0·1346.



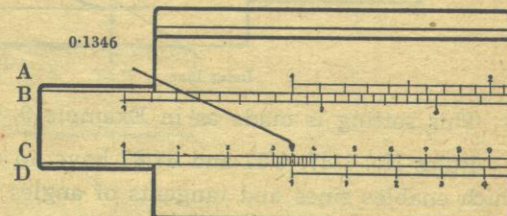


Fig. 9

Set the angle 7° 40' on the **T-scale** above the **left** hand **lower** index line and read the value of the tangent 0·1346 on **C** above **D** 1.

The cotangent of this angle will be found on scale **D** under 10 on **C**; it is 7·43. The reading of tangents must be divided by 10, while cotangents are as found on the **D** scale. On the rules which are fitted with reciprocal scales cotangents will be found on scale **Cr** in line with 1 on **D**.

Sines of angles from 34' to 90° and tangents and cotangents of angles from 5° 43' to 45° can be read in this way.

On Rules 4/98 the **T** scale is used with the upper scales. In this case the procedure is somewhat different, but it should be readily understood from the following example.

Example, Fig. 10: 7° 40' = 0·1346.

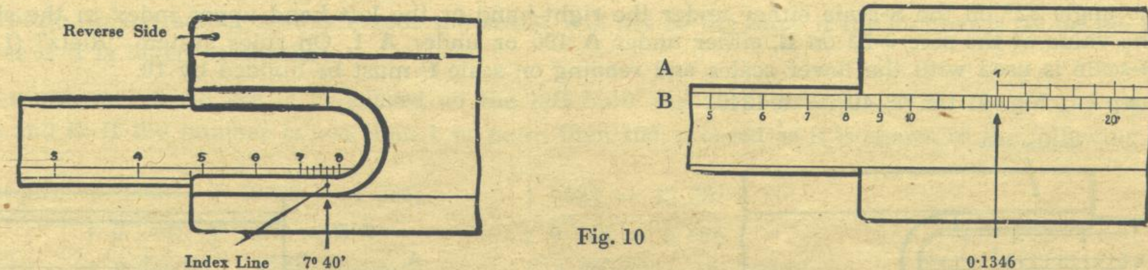


Fig. 10

This setting is made as in Example 9, but the reading is on scale **B** under 1 on **A**. It must be divided by 100.

Rules No. 1/87, 4/87 and 67/87 have, in addition to **S** and **T** scales on the back of the slide, a scale **S-T**, which enables sines and tangents of angles between 34' and 5° 43' to be found. Sines and tangents of such small angles are almost the same; the difference between sin 34' and tan 34' is only in the fourth decimal place, and that between the sine and the tangent of 5° 40' is about 0·0005. The right-hand lower index is used with **S-T** and the reading on scale **C** must be divided by 100. Cotangents, which are read on scale **D**, must be multiplied by 10.

E x a m p l e, Fig. 11: Sin 3° 38' or tan 3° 38' = 0·0634.

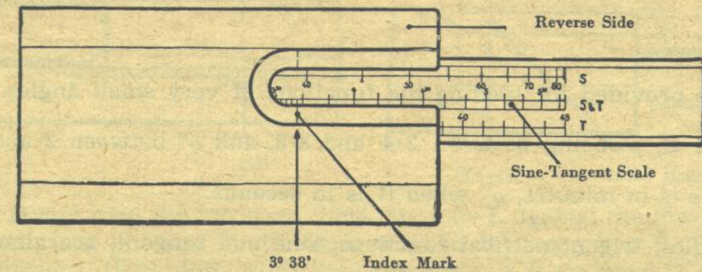
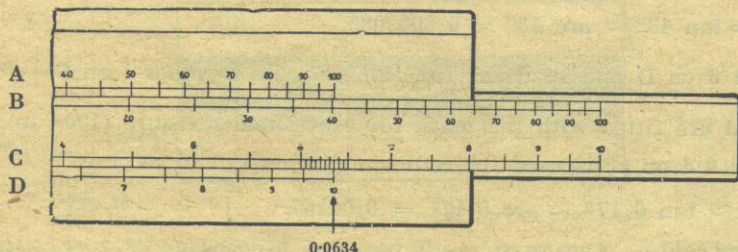


Fig. 11



Set the angle 3^0 38' on the **S-T** scale over the right-hand lower index line and read the required answer, 0·0634, on scale **C** over 10 on **D**.

When the cosine is required, use is made of the equation $\cos \alpha = \sin (90^0 - \alpha)$; also tangents of angles over 45^0 are found from $\cot \alpha = \tan (90^0 - \alpha)$.

Mark ρ' and ρ''

The marks ϱ' and ϱ'' are provided for reading the functions of very small angles.

Both are found on scale **C**, ϱ' being between 3·4 and 3·5, and ϱ'' between 2 and 2·1.

ϱ' is used when the angle is in minutes, ϱ'' when it is in seconds.

In the case of small angles, trigonometrical functions, sine and tangent, are almost identical with the arc.

Example: $\sin 17' \approx \tan 17' \approx \text{arc } 17' = 0{\cdot}00495$.

Set the mark ϱ' over 1·7 on **D** and read the function on **D** under 10 on **C**.

Example: $\sin 43'' \approx \tan 43'' \approx \text{arc } 43'' = 0{\cdot}0002085$.

Set the mark ϱ'' over 4·3 on **D** and read the function on scale **D** under 1 on **C**.

With the slide rules that are fitted with the mark for centesimal measure (100^g to the quadrant), the same graduation (between 6·3 and 6·4 on **C**) is used for centesimal minutes and seconds.

Example: $\sin 0{\cdot}17^g \approx \tan 0{\cdot}17^g \approx \text{arc } 0{\cdot}17^g = 0{\cdot}00267$.

$\sin 0{\cdot}0040^g \approx \tan 0{\cdot}0040^g \approx \text{arc } 0{\cdot}0040^g = 0{\cdot}0000628$.

Logarithms

The scale marked **L** on the back of the slide, enables the mantissa of the logarithm of a given number to be found.

Example, Fig. 12: log. 1·35 = 0·1303; log. 13·5 = 1·1303.

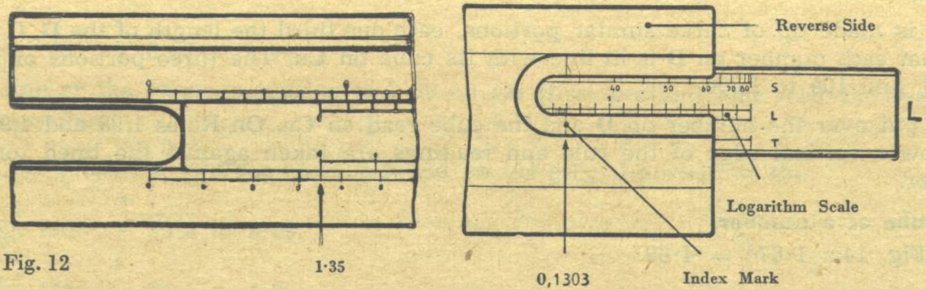


Fig. 12

Set 1 on **C** to 1·35 on **D** and read the mantissa, 1303, on scale **L** against the lower index line at the right-hand end of the rule. The characteristic is found in the usual way; in this case it is 0. Therefore log 1·35 = 0·1303.

On rules with **S-T** divisions, (1/87, 4/87, 67/87 etc.) the scale of logarithms is on the face of the rule. This scale is read with the help of the cursor.

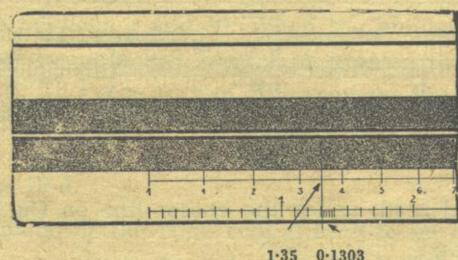


Fig. 13

Place the cursor line over 1·35 on scale **D** and read the answer on **L** under the cursor line.

The Cube Scale: CU

For the calculation of cubes and cube roots our slide rules are provided with a cube scale, **Cu**, which is used in combination with the **D** scale on the face of the rule. In reading both cubes and cube roots it is only necessary to use the cursor.

The scale **Cu** is made up of three similar portions, each one third the length of the **D**, **C** and **Cr** scale. Scale **Cu** is so placed that each number on **D** is in line with its cube on **Cu**. The three portions of scale **Cu** run from 1 to 10, 10 to 100, and 100 to 1,000.

The cursor is put over the number on **D** and the cube read on **Cu**. On Rules 1/98 and 4/98 the cube scale is situated on the lower vertical edge of the rule and readings are taken against the lined tongue on the lower edge of the cursor.

To find the cube of a number.

Example, Fig. 14a: $1{\cdot}67^3 = 4{\cdot}66$.

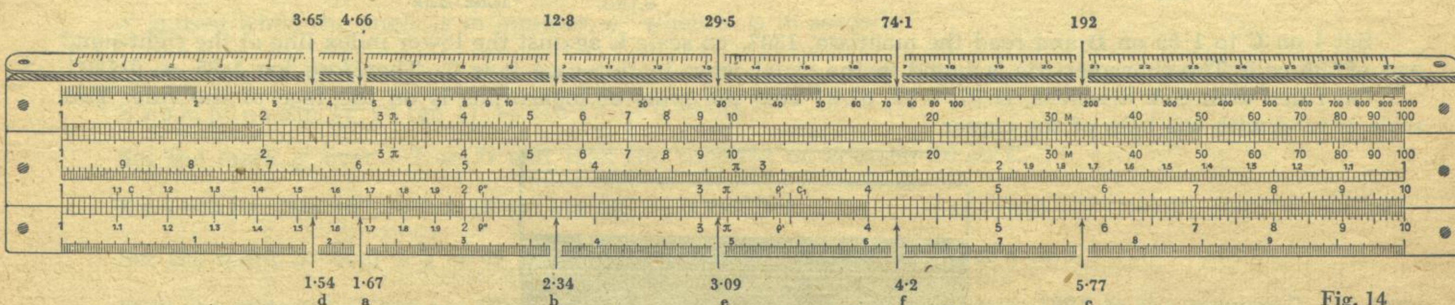


Fig. 14

Place the cursor line to 1·67 on **D**, and read, under the cursor line on **Cu**, the cube 4·66 (first portion).

Example, Fig. 14b: $2{\cdot}34^3 = 12{\cdot}8$.

Example, Fig. 14c: $5{\cdot}77^3 = 192$.

Cube Root

If the number is between 1 and 1,000, set the cursor to it on scale **Cu** and read the cube root under the cursor line on **D**.

Example, Fig. 14d: $\sqrt[3]{3{\cdot}65} = 1{\cdot}54$.

Set the cursor line or the cursor extension to 3·65 on **Cu** (first portion) and read the required root, 1·54, on **D** under the cursor line.

The number in the following two examples is found on the second portion of **Cu**.

Example, Fig. 14e: $\sqrt[3]{29{\cdot}5} = 3{\cdot}09$.

Example, Fig. 14f: $\sqrt[3]{74{\cdot}1} = 4{\cdot}2$.

The number in the following example is on the third portion of scale **Cu**.

Example, Fig. 14c: $\sqrt[3]{192} = 5{\cdot}77$.

In these examples the roots were between 1 and 10. When the number has a cube root less than 1 or greater than 10—i. e., when the number is itself less than 1 or greater than 1,000, the decimal point should be shifted **three** places to the right or left. The cube root of this may be found on **D**, and the decimal point must be moved **one** place back for each three places it was moved forward in the number.

Example, Fig. 14d: $\sqrt[3]{3650} = 15{\cdot}4$.

This is treated as 3·65 and the value of the cube root is seen to be 1·54. The decimal point in the number was shifted **three** places to the **left**, so it must be moved **one** place to the **right** in the root.

This rule is, of course, reversed for cubes.

E x a m p l e , Fig. 14a: $16{\cdot}7^3 = 4{,}660$.

As the number must only have one figure to the left of the decimal point, this example is taken as $1{\cdot}67^3$ and the power is read as 4·66. Since the decimal point in the number was shifted **one** place to the **left,** it must be moved **three** places to the **right** in the power. Thus the required answer is 4,660.

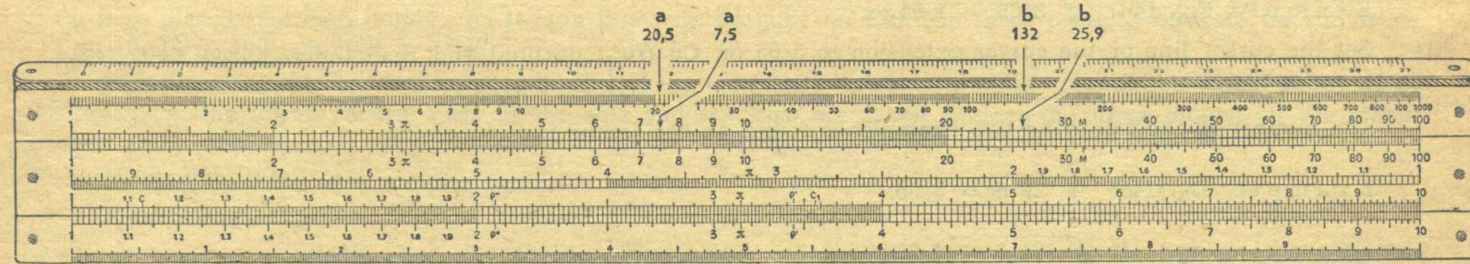


Fig. 15

If $a^{\frac{3}{2}}$ **is required,** set the cursor over a on scale **A** and read on **Cu** $a^{\frac{3}{2}}$

E x a m p l e , Fig. 15a: $7{\cdot}5^{\frac{3}{2}} = 20{\cdot}5$.

If $a^{\frac{2}{3}}$ **is required,** set the cursor line to a on the scale **Cu** and read on **A** the result $a^{\frac{2}{3}}$

E x a m p l e , Fig. 15b: $132^{\frac{2}{3}} = 25{\cdot}9$.

The possibilities of applying the rule are by no means exhausted by the above; one can obtain the values of a series of whole powers — e. g. all powers up to the ninth — and broken powers with positive or negative exponents, and can multiply or divide by similar powers of another number, but to develop here these combinations, which after all are relatively seldom employed, is outside the scope of this leaflet.

Cubes and Cube Roots (For Slide Rules without Cube Scale)

The methods used in raising a number to the third power or extracting the cube root will be understood from the following examples.

Example, Fig. 16: $2{\cdot}45^3 = 14{\cdot}7$.

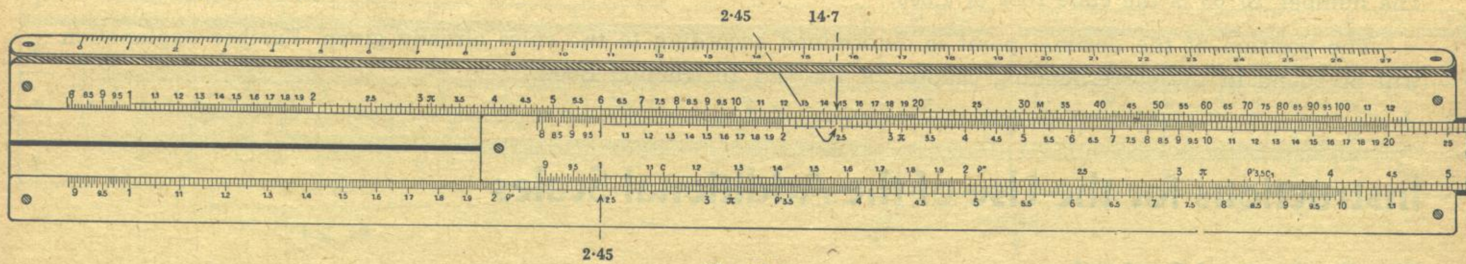


Fig. 16

Set 1 on **C** to 2·45 on **D** and bring the cursor line over 2·45 on **B.** The required power 14·7, is on **A** under the cursor line.

Example, Fig. 17: $\sqrt[3]{12} = 2{\cdot}29$.

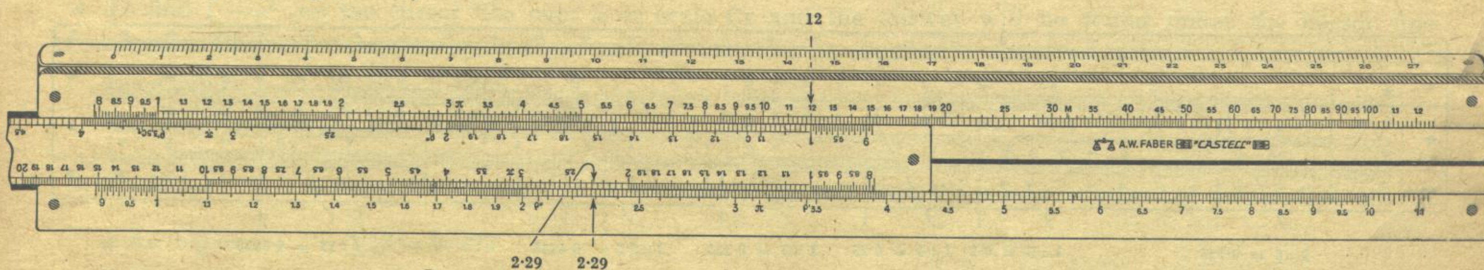


Fig. 17

Reverse the slide in the rule and set 1 on **C** under 12 on **A.** Then move the cursor along until the cursor line shows a position where equal numbers can be found on the lower rule scale, **D,** and on the now lower slide scale, **B.** This occurs at the number 2·29. Besides this, there is another pair of equal numbers on **D** and **B** at a different position. This is 10·63 on **B,** which corresponds with the same significant figures, 1·063, on **D.** The number 10·63 is the cube root of 1,200.

The position of the decimal point is determined according to the rules already given. Further explanation will be found in the corresponding chapter of the full Instruction Book.

Instructions for the Use of the Additional Scales

The Reciprocal Scale Cr

1. In order to find the reciprocal value 1 ÷ a for any given number a, find a on **C** (or **Cr)** and read above it on **Cr** (or below it on **C)** the reciprocal value. Reading off is done therefore without any movement of the slide and entirely by setting the cursor line. (Fig. 18).

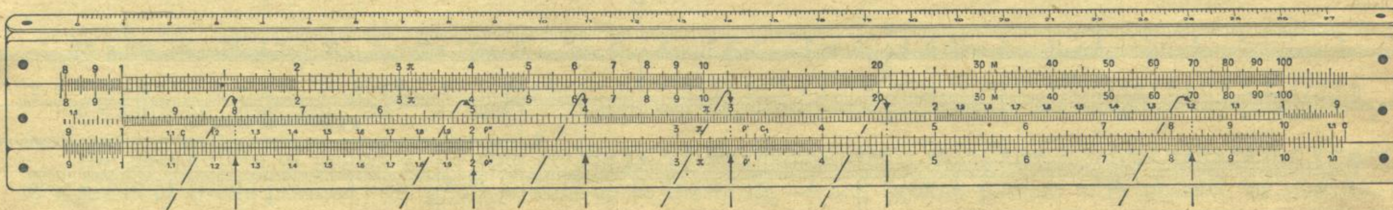


Fig. 18

2. To find $1 \div a^2$ move the cursor to a on scale **Cr** and read above it on **B** the result.

Example, Fig. 19 a: $1 \div 2{\cdot}44^2 = 0{\cdot}168$.

Estimated answer — less than $\frac{1}{5} = 0{\cdot}2$.

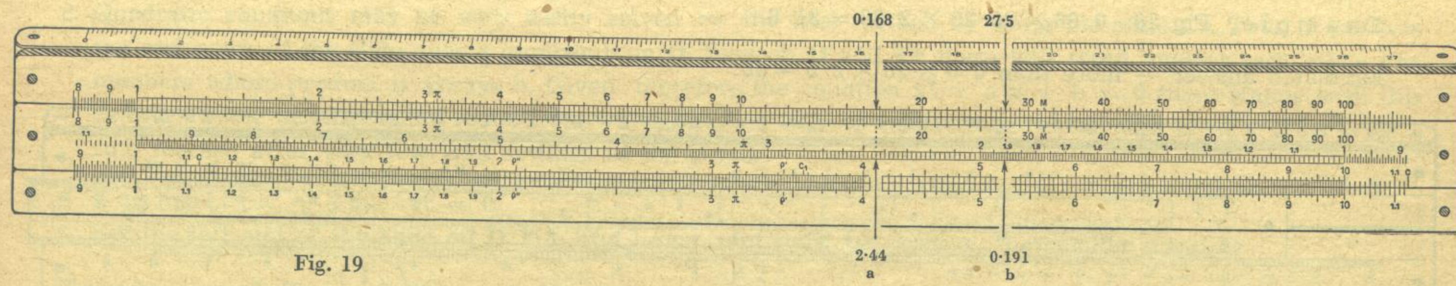


Fig. 19

3. To find $1 \div \sqrt{a}$, set the cursor line to a on scale **B** and find below it on **Cr** the result.

Example, Fig. 19b: $1 \div \sqrt{27{\cdot}5} = 0{\cdot}191$.

Estimated answer — less than $\frac{1}{5} = 0{\cdot}2$.

4. To find $1 \div a^3$, set the cursor line over a on scale **Cr** and the answer will be found under the cursor line on scale **Cu.**

Example: $1 \div 2{\cdot}26^3 = 0{\cdot}0866$.

Estimated answer — less than $\frac{1}{8} = 0{\cdot}125$.

5. To find $1 \div \sqrt[3]{a}$, move the cursor line to a on scale **Cu** and read the answer under the cursor line on **Cr.**

Example: $1 \div \sqrt[3]{13} = 0{\cdot}425$.

Estimated answer — less than $\frac{1}{2} = 0{\cdot}5$.

6. **Products of three factors** can generally be reached with one setting of the slide. One sets, by means of the cursor, the first two factors against each other on **D** and **Cr** respectively, moves the cursor to the third factor on **C** and reads below it on **D**, the final product.

E x a m p l e, Fig. 20: $0 \cdot 66 \times 20 \cdot 25 \times 2 \cdot 38 = 31 \cdot 8$.

Estimated answer — more than $0 \cdot 6 \times 20 \times 2 \cdot 5 = 30$.

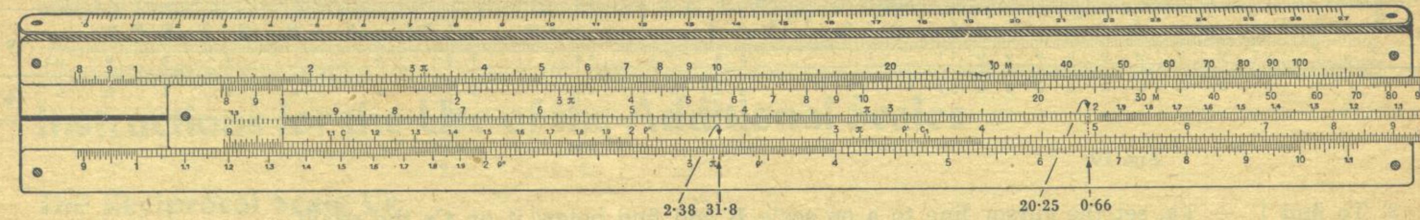


Fig. 20

In doing this it is occasionally necessary to move the slide over. (See General Instructions.)

E x a m p l e, $6 \cdot 05 \times 3 \cdot 24 \times 7 \cdot 15 = 140 \cdot 2$.

7. **Division by two divisors** can be worked out by reversing this procedure. Set the two divisors by means of the cursor against each other on **D** and **Cr,** then shift the cursor to the dividend on scale **D** and find the answer above it on **C.**

E x a m p l e: $\frac{44}{4 \cdot 85 \times 3 \cdot 66} = 2 \cdot 48$.

Estimated answer — about $\frac{45}{5 \times 3} = 3$.

Also in this case it may be necessary to shift the slide over as in the following.

Example: $\frac{125}{4 \cdot 85 \times 3 \cdot 66} = 7 \cdot 042.$

8. Quadratic equations may be very easily solved by the trial method by using the scale **Cr.** Thus if one sets the end mark of the slide over a number b on **D,** then on **D** and **Cr** there will stand against each other two numbers whose product is always b. Given therefore the equation $x^2 + a\,x + b = 0$ there stands with this setting a table of all possible roots, from which one has only to select those whose sum is — a. This is as a rule reached after very few trial settings of the cursor.

Example: $x^2 - 4\,x - 18 = 0.$
Set the left end of the slide on **D** 1·8. The larger root must be positive, the smaller negative.

Trials:			
	—2·60	—2·70	—2·69
	+6·92	+6·67	+6·69
	+4·32	+3·97	+4·00
	+ 32	— 3	
	≈ 11 : 1		

The last two numbers are therefore the roots.

9. **Cubic equations** can be solved in a similar manner, if they can be reduced to the form $x^2 + \frac{b}{x} = a$. Set one end of the slide to b on scale **D,** move the cursor at random to any x on the scale **D,** then on **Cr** above it will stand the value $\frac{b}{x}$ and above on **A** the square x^2. If these two numbers add to a, then x is a root of the cubic equation.

Example: $x^2 + \frac{17}{x} = 13.$

Set the left end of the slide on **D** 1·7, and make trials as follows:

$x =$	2·40	2·50	2·475	—4·10	—4·20	—4·135
$\frac{17}{x} =$	7·08	6·80	6·87	—4·15	—4·05	—4·11
$x^2 =$	5·76	6·25	6·13	16·81	17·64	17·11
	12·84	13·05	13·00	12·66	13·59	13·00
	—16	+ 5		—34	+59	
	$\approx$ 3 : 1			$\approx$ 1 : 2		

2·475 and — 4·135 are therefore two of the roots, the third is 1·66, from the fact that all three together equal 0.

The log-log scale

The log-log scale begins in the left top corner with 1·1 and extends to 3·2 (**LU**), and then continues below from the left, the portion from 2·5 to 3·2 being repeated, and ends on the right below with 100,000 (**LL**). These two portions of the log-log scale are arranged in relation to each other and to the lower scale in a particular manner, which renders numerous applications possible.

1. Under each number of the upper log-log scale stands on the lower log-log scale its tenth power

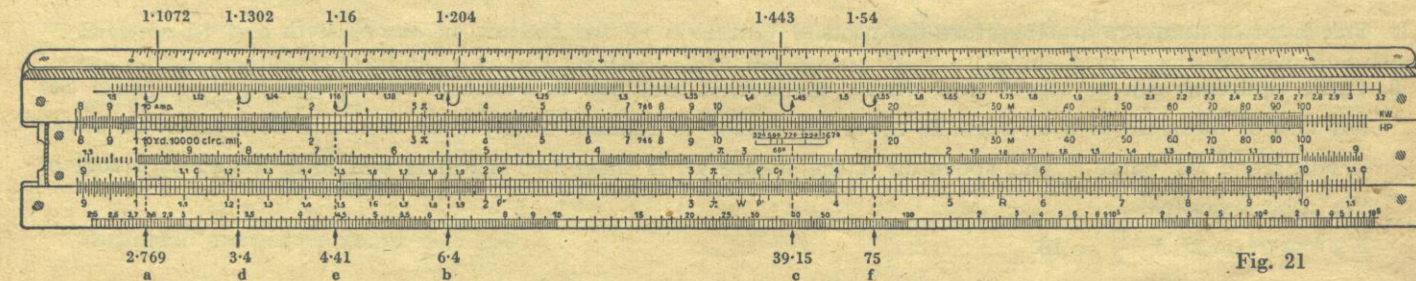


Fig. 21

The cursor line is used for setting.

Example: $1{\cdot}1072^{10} = 2{\cdot}769$ (Fig. 21a) $1{\cdot}204^{10} = 6{\cdot}4$ (Fig. 21b) $1{\cdot}443^{10} = 39{\cdot}15$ (Fig. 21c)

2. Over every number on the lower log-log scale (**LL**) stands on the upper log-log scale (**LU**) the tenth root.

   Example: $\sqrt[10]{3{\cdot}4} = 1{\cdot}1302$ (Fig. 21d) $\sqrt[10]{4{\cdot}41} = 1{\cdot}16$ (Fig. 21e) $\sqrt[10]{75} = 1{\cdot}54$ (Fig. 21f).

3. Under every number **n** on scale **D** of the rule will be found e^n on the lower log-log scale (**LL**).

   Example: $e^2 = 7{\cdot}39$ (Fig. 22a), $e^3 = 20{\cdot}1$ (Fig. 22b).

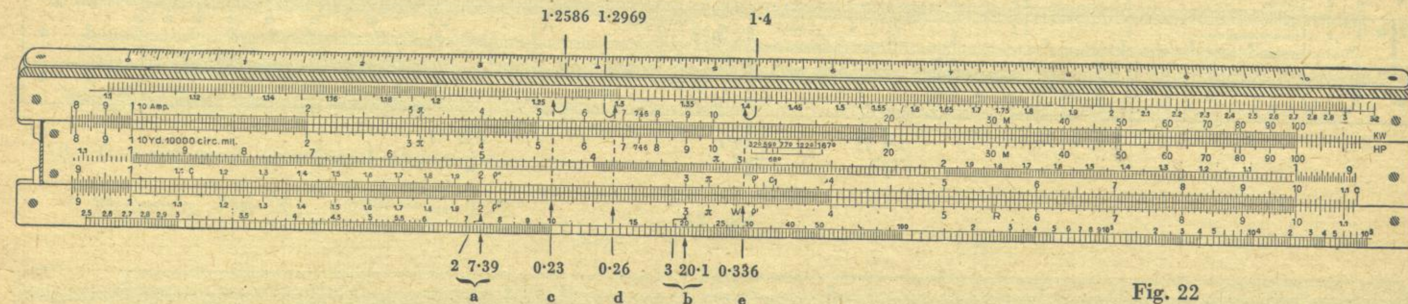


Fig. 22

4. Over every number **n** on the lower scale (**D**) stands $e^{\frac{n}{10}}$ on the upper log-log scale (**LU**).

   Example: $e^{0{\cdot}23} = 1{\cdot}2586$ (Fig. 22c) $e^{0{\cdot}26} = 1{\cdot}2969$ (Fig. 22d) $e^{0{\cdot}336} = 1{\cdot}4$ (Fig. 22e).

5. If roots of e have to be extracted, then the exponent (such as 5) can be converted into a decimal $(0 \cdot 2)$ and the procedure in paragraph 4 followed. If the exponent is a fraction, scale **Cr** may be used.

   Example: $\sqrt[2{\cdot}17]{e} = 1{\cdot}5853$ (Fig. 23a).

6. If e^{-n} has to be worked out, read off first e^{+n} and then work out on the rule the reciprocal value.

   Example: $e^{+5{\cdot}2} = 181{\cdot}3$, therefore $e^{-5{\cdot}2} = 0{\cdot}00551$.

7. If the exponential equation $e^x = a$ has to be solved, set a, according to its magnitude, either on the upper or lower log-log scale, and read x on the lower scale **D** of the rule.

Example: $e^x = 20{\cdot}1 \quad x = 3$ (Fig. 23b) $\quad e^x = 11 \quad x = 2{\cdot}4$ (Fig. 23c).

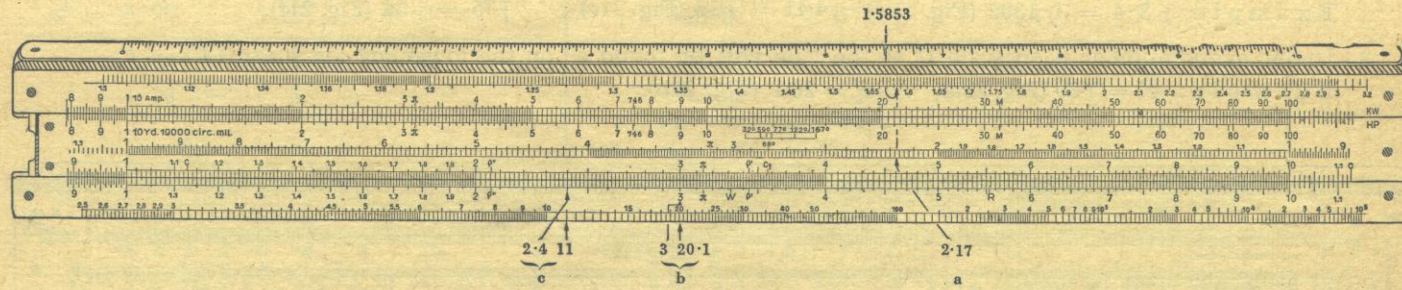


Fig. 23

8. If it is desired to calculate exponential equations of the form $e^{\frac{1}{y}} = \sqrt[y]{e} = a$, without determining the reciprocal value, this can be effected with the scale **Cr.**

Example: $\sqrt[y]{e} = 1{\cdot}485$, $y = 2{\cdot}529$ (Fig. 24a).

9. The values on scale **D** are the hyperbolic logarithms of the numbers on the log-log scale, so that the rule gives at once a table of hyperbolic logarithms ($\log_e$).

Example: $\text{Log}_e\, 94 = 4{\cdot}54$ (Fig. 24b) $\quad \log_e 1{\cdot}87 = 0{\cdot}626$ (Fig. 24c).

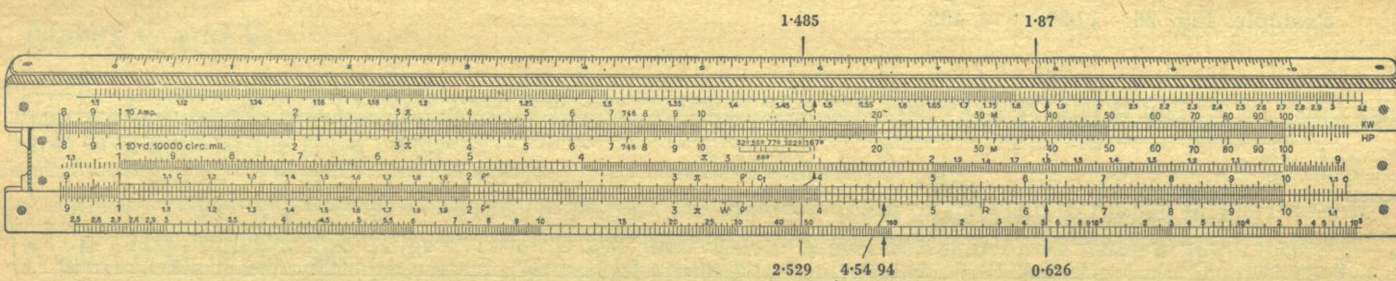


Fig. 24

Up to the present the cursor line only has been used; if the slide is employed then the following methods of calculation become possible.

10. Powers with fractional exponents.

Example, Fig. 25: $1{\cdot}277^{2{\cdot}22} = 1{\cdot}72$.

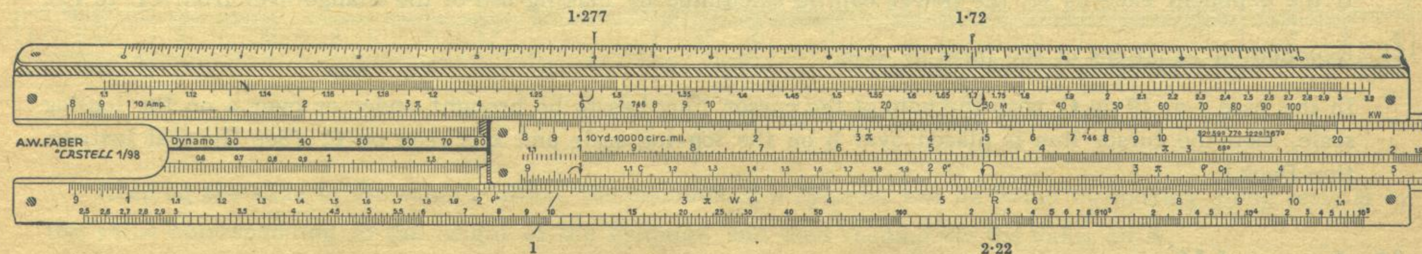


Fig. 25

With the cursor line, set 1 on scale **C** under 1·277 on scale **LU** and over 2·22 on **C** read 1·72, the required answer, on **LU** (Fig. 25).

Example, Fig. 26: $11{\cdot}5^{2{\cdot}53} = 483.$

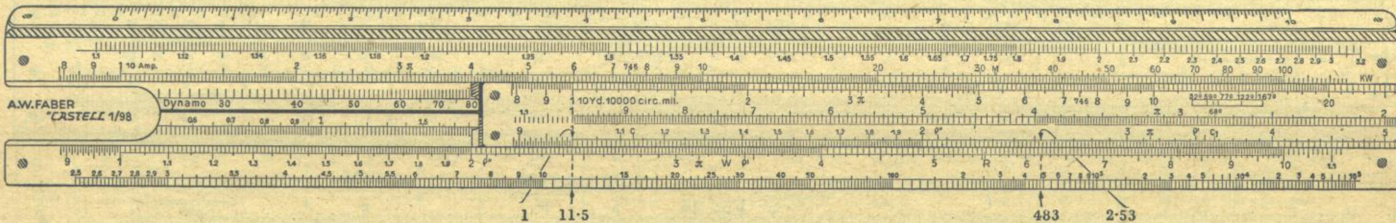


Fig. 26

In this case one has to set and read off on the lower log-log scale (**LL**).
If the division mark on **C** falls outside to the right, so that it is not possible to read above or below it, set the right end division (**C** 10) under the basis number.

If the exponent exceeds 10, the power can be calculated by making use of the change over from **LU** to **LL.**

11. Exponential equations of the form $a^x = b$.

In this case 1 or 10 on **C**, with the help of the cursor line, has to be brought under or over a on the log-log scale, then the cursor line is placed over b on the log-log scale and x is read on **C**. (See General Instruction Book.)

Marks π and M

In order to facilitate calculations of circles there is a special mark on the rule for the number π. As it is often as useful to have the reciprocal value of π, there is also the mark **M** which represents the value $1 \div \pi$.

Marks C and C_1

Set C or C_1 on scale **C** over a given diameter on **D** and then on **A** above **B** 1, **B** 10 or **B 100** will be found the area of a circle of the given diameter.

Select that one of the two marks which permits the greatest length of the slide to remain in the rule body. Example, Fig. 27a: Set C_1 (or C) over **D** 2·82 and read on **A** over **B** 1 or **B** 10 the value 6·24 sq. inch.

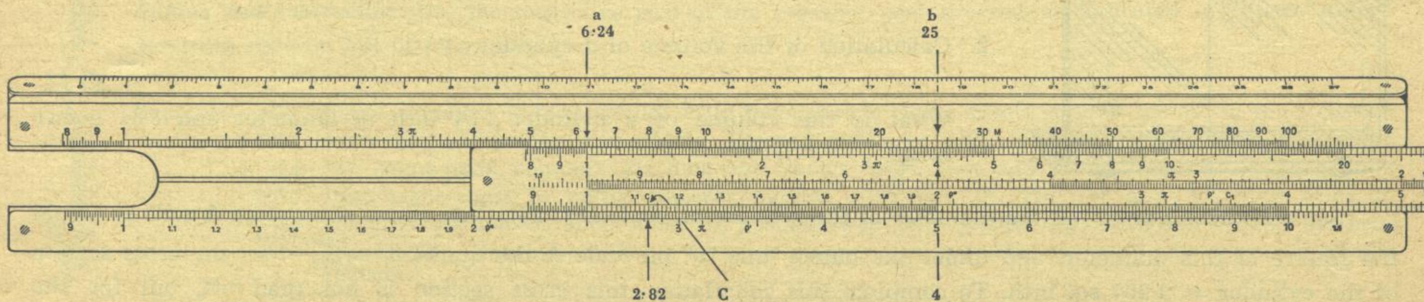


Fig. 27

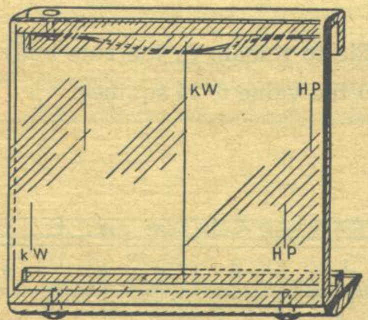
Keeping the slide in the same position, the contents of a cylinder can be found by looking along scale **B** to the value corresponding to the height of the cylinder, and then reading off the value on **A**.

Example, Fig. 27b: If the height of the cylinder is 4 inch. the contents will be found = 25 cub. inch.

In the same manner the useful value $\frac{\pi}{4} = 0 \cdot 7854$ is marked by a small line on the **A** and **B** scales.

Instructions for the use of the cursor.

This special cursor with unequal constants has five lines, which make possible several very important mathematical operations.



1. Calculation of the area of a circular cross section from a given diameter.

   Set the centre or the lower right hand cursor line "d" over the diameter, 3·2 inches, on the lowest scale **D,** and read on the upper scale, **A,** under the adjacent cursor line "s" to the left, the area 8·04 sq. inches.

2. Calculation of the volume of a cylinder.

   What is the volume of a cylinder 1·24 inch in diameter and 3·24 inches long?

Set the cursor line "d" on the diameter of the cylinder on scale **D** (1·24), then above it on scale **A** will be found the square of this diameter, and under the cursor line "s" on scale **A** the quotient $\frac{1{\cdot}24^2}{1{\cdot}273}$ = the cross section of the cylinder = 1·207 sq. inch. To complete this calculation this cross section is not read off, but for the determination of the volume, the value under the cursor line "s" will ordinarily be multiplied by the length 3·24 inches. The required volume = 3·91 cub. inches.

3. Changing of Watts into HP and HP into Watts.

E x a m p l e : How many Watts are 48 HP?

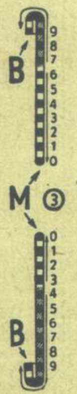
Set the cursor line "HP" over 48 on scale **A.** Under the cursor line "W" will be found 35,800 Watts on scale **A.**

For more accurate calculation set the cursor line "HP" over 48 on **D.** Under the cursor line "W" will be found 35,810 Watts on scale **D.**

ADDITION AND SUBTRACTION BY THE ADDIATOR MACHINE

DIRECTIONS FOR USE.

To clear register. Pull up the metal slide on the top of the machine, and then push it down again.



Before operating, see that the middle Register is set at zero. Should an Y sign remain after clearing the machine, insert stylo in the "1" in corresponding column above and pull towards the middle. (Limit "M".) Pay no attention at this stage to square-holed register at bottom.

Adding and subtracting. Use the respective part of the machine, and proceed as indicated in **"Short Rules"**, inserting stylo on left of figure required.

Example:	673	Insert numbers as you would write them (left to right). Insert stylo in the "6" in third column
	+5269	from right and pull towards middle. Proceed similarly with "7" (2nd column from right) and
	+ 734	"3" (right-hand column). Machine now shows "673". Now add "5269". The "5" in 4th column
	6676	from right must be pulled towards middle. Also the "2". The "6" and "9", both being in
	— 845	coloured portion of slide must be pushed away from middle (upwards) and around the bend
	5831	to limit "B". Now insert "734" in the same manner, and sub-total of "6676" will appear in middle register.

To subtract "845" use subtraction part. The "8" in 3rd column from right, being coloured, must be pulled away from middle (downwards) and around the bend to limit "B". The "4" and "5" are to be pushed upwards to middle. Correct total is now shown in middle register of "5831".

AUTOMATIC STOPPAGE.

If a movement has been made in the wrong direction, i. e., pushed up instead of down or vice-versa, the mistake will be indicated automatically by stoppage of the machine so that the wrong movement will not be continued. In this case, you merely leave the stylo in the relative hole and move it to the opposite limit, and the correct total will be shown.

Arrow signal.

Should an "arrow" appear in either the middle or bottom register, it should be eliminated by inserting the stylo in the "0" of corresponding column — addition or subtraction according to direction of arrow — and moving same, upwards or downwards, around the bend to limit "B".

Pay no attention to arrows in bottom register unless calculating with negative results.

Example:
756
+149
905

After insertion of the numbers an ⅄ appears in 2nd column from right in middle register, which is eliminated by inserting stylo in "0" in 2nd column from right — addition portion — and pushing it upwards and around to limit "B" when correct answer of "905" will appear. If the operator omits to eliminate the signal, the machine will continue to function correctly, but later a stoppage might occur in the bends, preventing the stylo from reaching limit "B". When this occurs, the signal must be cleared from the "1" tho limit "B".

Example:
199
\+ 5
\+ 8
212

After insertion of the "199" and "5" it will be found impossible to move the "8" right around to limit, but by clearing the arrow from "1" in 2nd, column, correct answer of "212" will be shown.
When subtracting a larger amount from a smaller one, an arrow will appear on the left of the figures in middle register signifying that the answer will be found in bottom register, where also a "—" sign will be shown. The figures to the right of the minus sign represent the answer, and notice is to be taken of the figures on the left of this sign.

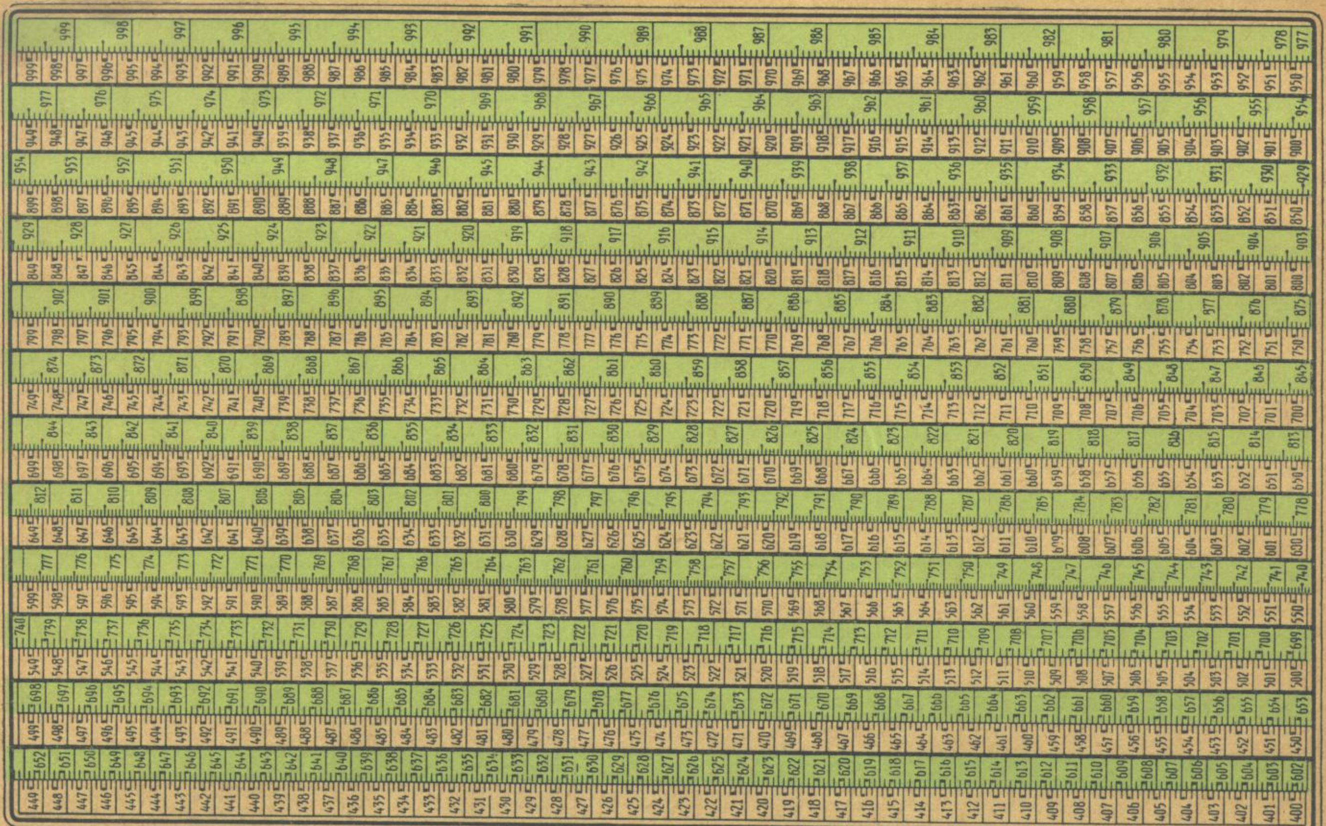
Example:
634
—857
—223 will appear in bottom register as negative result
+536 is added in addition part
313 will appear in middle register as correct answer.

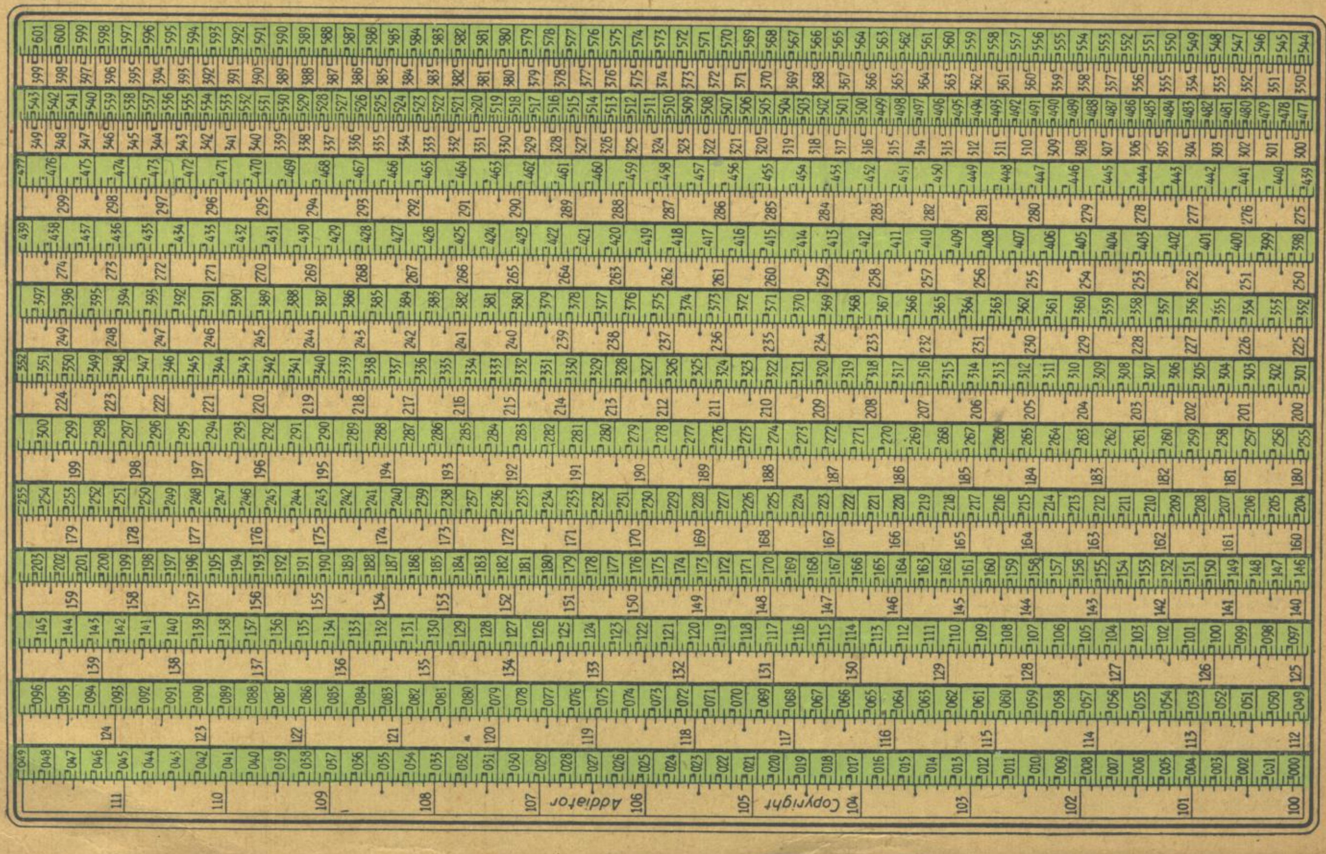
On certain occassions, two minus signs will appear in bottom register, in which case the right-hand one must be eliminated in the same manner as an Y is treated.

Example:
600
—800
—200

After insertion of the figures and eliminating the Y sign in right-hand column — subtraction part — the answer will read "—1—0". By eliminating right-hand minus sign, as instructed, answer of — "200" will be shown.

Important. Before operating, see that middle register is set at zero.

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