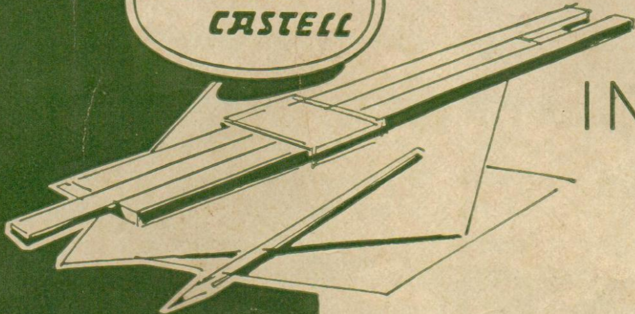


FABER-CASTELL

INSTRUCTIONS

for Use of

CASTELL PRECISION

SLIDE RULES

1/60 1/87 111/87 4/87
for Mechanical
and Constructional Engineers

1/92 1/98 111/98 4/98
for Electrical Engineers
and Physicists

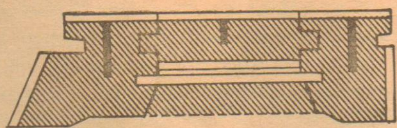
A. W. FABER-CASTELL · STEIN NEAR NUREMBERG

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 should be handled with care.

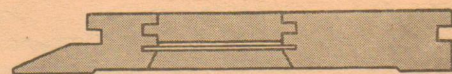
Slide Rules of Specialised Wood Construction

are impervious to climate; they should nevertheless be protected from any considerable temperature fluctuations and from humidity. The resilient base gives the Slide Rule great elasticity, making it easier to move the slide and adjust its mobility. There are metal inserts ensuring exceptional stability in the basic structure of the Slide Rule and preventing deformation by climatic influences.



Slide Rules of Geroplast

are absolutely "climate-proof", as well as heat-proof and damp-proof, and they stand up to the effects of the majority of chemicals. Geroplast Slide Rules should not, however, be allowed to come in contact with corrosive liquids or strong solvents, as these — even if the material itself remains unaffected — are at any rate liable to cause the colour of the graduation marks to deteriorate.



The following applies both to Wood Slide Rules and to Geroplast Rules:

To preserve the legibility of the graduations, the facial scales and the cursor should be protected from dust and scratches, and cleaned at frequent intervals with the special CASTELL cleaning agent No. 211 (liquid) or No. 212 (in paste form).

Never clean them with alcohol!

Description of the Slide Rule

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 calculation 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.

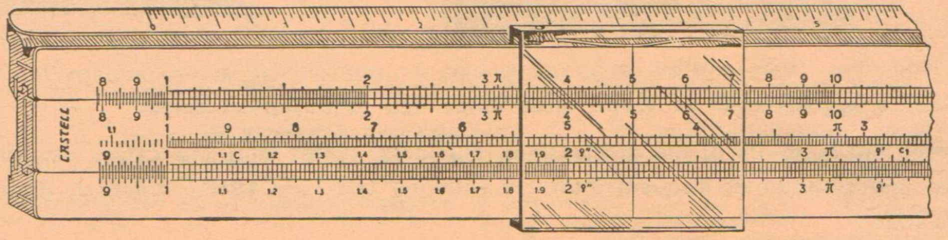
Definition

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 lines across it, is the "cursor". —

For convenience, the scales are described by different letters.

The main scales.

Fixed scale of squares A (x^2)
Movable scale of squares B (x^2)
Scale of reciprocals CI $\left(\frac{1}{x}\right)$
Movable base scale C (x)
Fixed base scale D (x)



The Additional Scales

Fixed scale of cubes	K (x^3)	on the upper part (slide rules 1/87, 111/87, 4/87) or on the lower vertical edge (slide rules 1/92, 1/98, 111/98, 4/98)
Movable scale of sin and cos	S ∢ sin 0·1x	on the back of the slide
Movable scale of tg and ctg	T ∢ tan 0·1x	on the back of the slide
Movable Radian scale	ST ∢ arc 0·01x	on the back of the slide (slide rules 1/87, 111/87, 4/87)
Movable Mantissa scale	L log x	on the back of the slide (slide rules 1/60, 1/92, 1/98, 111/98, 4/98)
Fixed Mantissa scale	L log x	on the lower part (slide rules 1/87, 111/87, 4/87)
Fixed log-log-scales for positive exponents	LL_2 $e^{0\cdot1x}$	on the upper part (slide rules 1/92, 1/98, 111/98, 4/98)
	LL_3 e^x	on the lower part (slide rules 1/92, 1/98, 111/98, 4/98)
fixed efficiency-scale	W	under the slide on the body (slide rules 1/98 and 4/98)
fixed pressure drop scale	V	on the lower face of the rule (slide rule 111/98)

Reading the Scales

Slide Rules with graduated length 10 inch.

Subdivision 1 to 2

Let us first turn our attention to the lower scales, **C** and **D.** Here it should be noted that the tenths are shown and numbered between **1 and 2,** these tenths in their turn being subdivided in a like manner (hundredths). The division-marks are thus read off as follows from the start: 100-101-102-103 . . . . 109-110-111-112-113 . . . . 198-199-200.

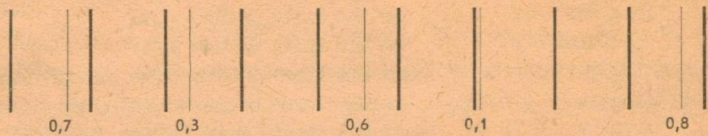
Exercises: Set the cursor with its hair line over the following values: 175, 163, 157, 130, 103, 170, 107, 111, 191.

When calculating with the slide rule, however, we are not merely concerned with numbers shown by a mark on the scales. We must also be able to set the cursor-line correctly to further imaginary subdivisions in between the hundredths (that is, to thousandths). This is by no means so difficult as it first appears. Firstly practice finding the exact centre.

Exercises: Set the cursor-line to 1075, 1355, 1675, 1425, 1985, 1705, 1075.

For all other values it is advisable to work from the centre-position outwards, so that if the cursor has to be set, for example, to 1074, it should first be placed so that its line is in the right position for 1075 and then moved slightly to the left. If the value desired is 1688, one starts at 1690 and then goes back a little way. After a certain amount of practice the positions of the tenths can be satisfactorily estimated.

The setting of the cursor-line between two adjacent division-marks is an operation which the user must practice regularly. The best way of doing this is to draw two vertical lines at a distance of about 10 mm. and then placing a thread on each tenth of the distance in turn, judging the position with the eye in each case. One can then use a ruler to check ones accuracy of judgment.



Exercises: Place cursor-line over 1172, 1784, 1098, 1346, 1777, 1007, 1703.

Finally, set the cursor-line somewhere between 1 and 2 and read off the number denoted by that position.

Subdivision from 2 to 4.

Now let us consider our next division, that extending from **2 to 4.** Here we first find the tenths marked, as before, but the only further divisions marked are the fifths. The values from 2 onwards are: 200-202-204-206-208-210-212 . . . . 396-398-400. In setting the odd hundredths, therefore, the position must be judged with the eye.

Exercises: Place cursor-line over the values 207, 347, 277, 209, 315, 373.

In this section it is recommended that the beginner should not for the moment attempt to set the cursor to thousandths. If he requires 2358, for instance, he should round it off to 236, 2073 being rounded off to 207, and so forth.

Finally, the cursor is placed at any desired point between 2 and 4, the user endeavouring to take an accurate reading of the result.

Subdivision from 4 to 10.

From 4 onwards to the end of the lower scales, only the halves are marked between the tenths. After 4, therefore, readings are taken as follows: 405-410-415 etc., up to 995-1000. All the other hundredths must be judged with the eye. First place the cursor-line over the following easier numbers: 4225; 7875; 9175; 6025, etc. If the setting required is 423, the best method is to begin with 4225 and then to move the cursor-line a little towards the right. For 787 one starts with 7875, then moving a little to the left.

Exercises: Set to 633; 752; 927; 538; 467.

For 444 and 446 one starts with 445 and then moves to the left or to the right respectively. On the same principle one starts at 790 for 789 or 791.

Exercises: Set to 908; 426; 709; 627; 517.

The user is also advised to select numbers of his own for setting and reading.

Slide Rules with graduated length 20 inch.

If one is using a slide rule with a graduated length of 20 inch the subdivision is naturally different. It is explained briefly below: —

The large slide rules with a graduated length of 20 inch are divided up as follows: on **C** and **D**, between 1 and 2, we first find the tenths, then tenths of the latter (hundredths) and finally the halves of these further tenths, i.e. the two-hundredths. Our readings are thus: 1005-1010-1015-1020 etc. up to 1990-1995 and 2000. From 2 to 5 the tenths are marked and then further subdivided into tenths (i. e. hundredths). Our readings are thus: 201-202-203 to 498-499 and 500. From this point onwards to the end of the scales the tenths are marked, with fifths in between them (fiftieths). The readings are therefore: 502-504-506 etc. up to 996-998 and 1000.

On the upper scales of the large slide rules the interval between 1 and 2 is subdivided in the same way as that between 2 and 5 on the lower scales, the subdivision of the interval between 2 and 4 corresponding to that between 5 and 10 below, while in the interval between 4 and 10 only the halves of these subdivisions, i. e. the twentieths, are marked, so that the readings are: 405-410-415 etc. up to 990-995-1000.

Accuracy of the Reading

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.

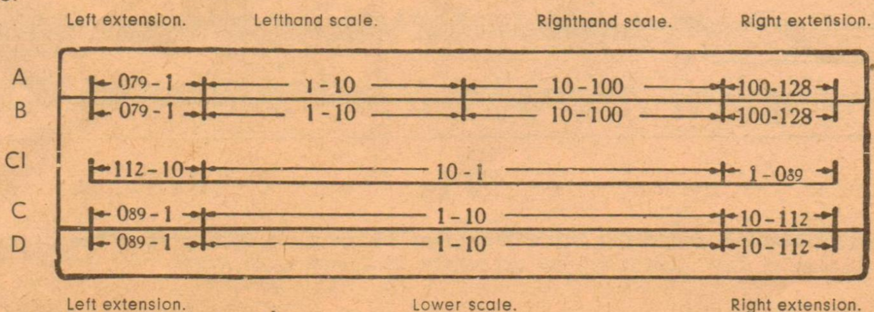


Fig. 1

The Decimal Point

As the upper scales, **A** and **B**, run from 1 to 100, and the lower from 1 to 10, a novice is inclined to think that it is only possible to use the slide rule for numbers within these limits. This is not so, since the position of the decimal point is ignored in slide rule working. For instance, to multiply 320 by 580, it would be possible to multiply 3·2 by 5·8 and increase the answer ten thousand times, or in other words, move the decimal point four places to the right. The graduation 3 on any of the scales may be taken to represent 30, 300, 3,000, etc., or 0·3, 0·03, 0·003, etc. In slide rule working significant figures only are considered, and the position of the decimal point is found from a rough estimate of the size of the answer. In practical problems the number of figures is obvious.

Instructions for the Use of the Main Scales

Multiplication

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

Example, Fig. 2: $6 \times 3{\cdot}5 = 21$.

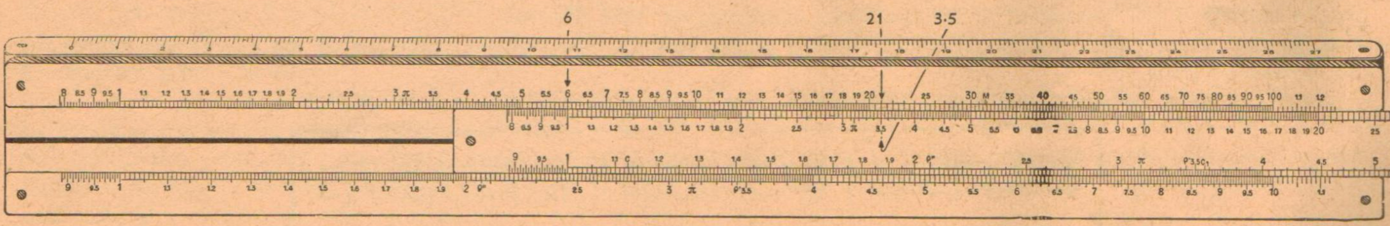


Fig. 2

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. (Fig. 3)

Example, Fig. 3: $2{\cdot}5 \times 3 = 7{\cdot}5$.

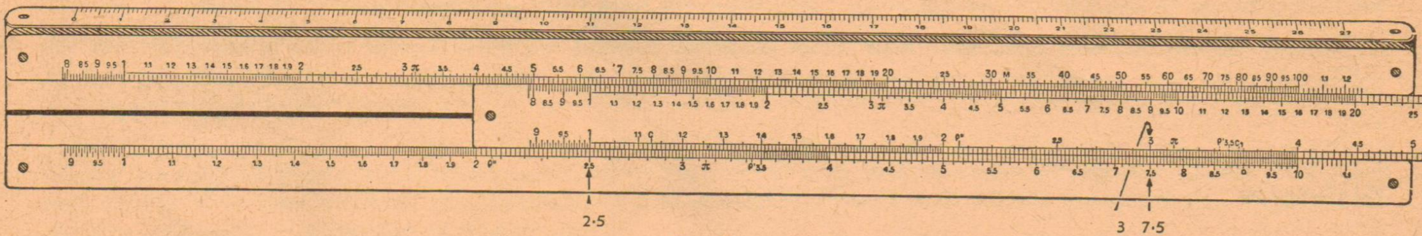


Fig. 3

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. (Fig. 4)

Example, Fig. 4: $7{\cdot}5 \times 4{\cdot}8 = 36$.

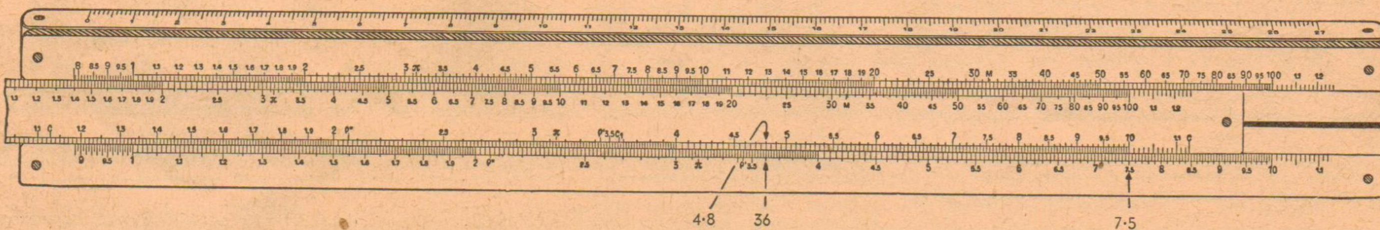


Fig. 4

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 to 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

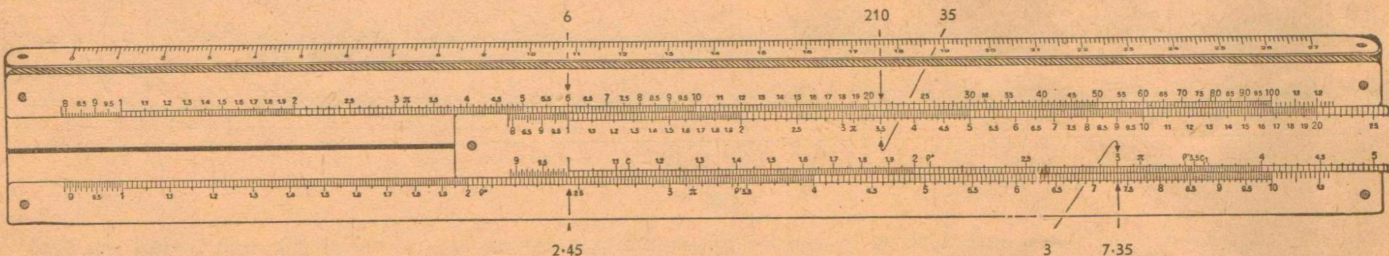


Fig. 5

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

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.

Example: $\frac{13{\cdot}8 \times 24{\cdot}5 \times 3{\cdot}75}{17{\cdot}6 \times 29{\cdot}6 \times 4{\cdot}96}$ We start by dividing 13·8 by 17·6. Therefore we place

A 138 and **B** 176 one under the other. Do not read off the answer — approximately 0·8 — but multiply it immediately by 24·5, by placing the cursor-line on **B** 245. Similarly, no reading is taken of the answer — about 19 — and it is simply divided by 29·6. For this purpose, keep the cursor-line firmly in its position and slide **B** 296 under it. Once again, the result (0·65) is not "read" but multiplied at once by 3·75, this being done by placing the cursor-line on **B** 375. The result is merely "retained" by the cursor-line, as before, and divided by 4·96, by sliding **B** 496 under the cursor-line. Only then do we read off the figures of the final answer, 491, above **B 10** and **B 100** — and our rough calculation shows us that the actual answer is 0·491.

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: $3^2 = 9$.

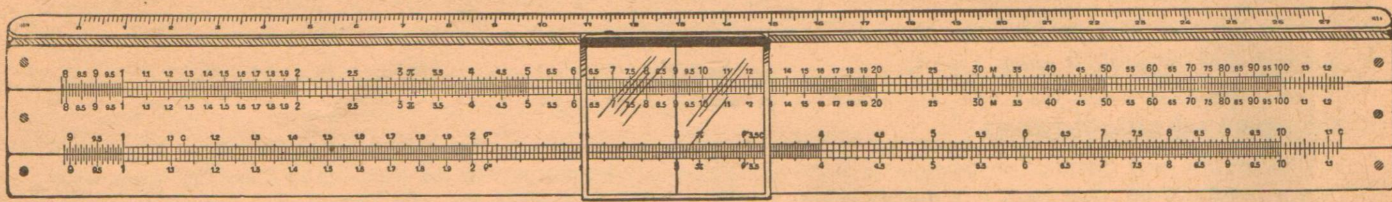


Fig. 6

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

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

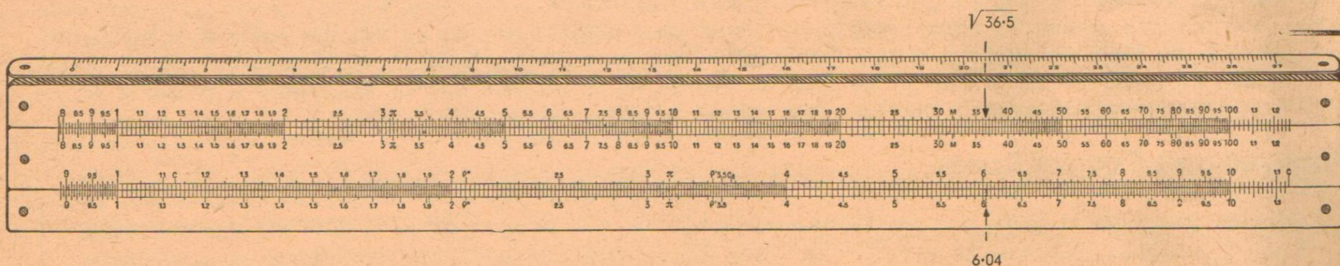


Fig. 7

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.

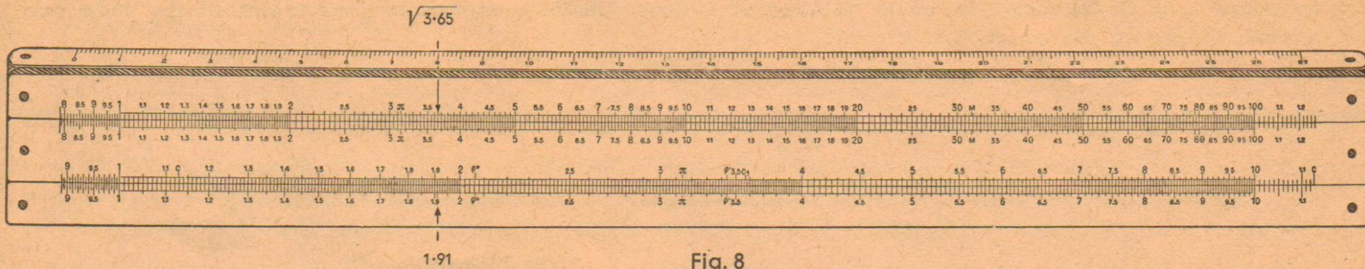


Fig. 8

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.

The Reciprocal Scale CI

1. In order to find the reciprocal value 1 ÷ a for any given number a, find a on **C** (or **CI**) and read above it on **CI** (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. 9.)

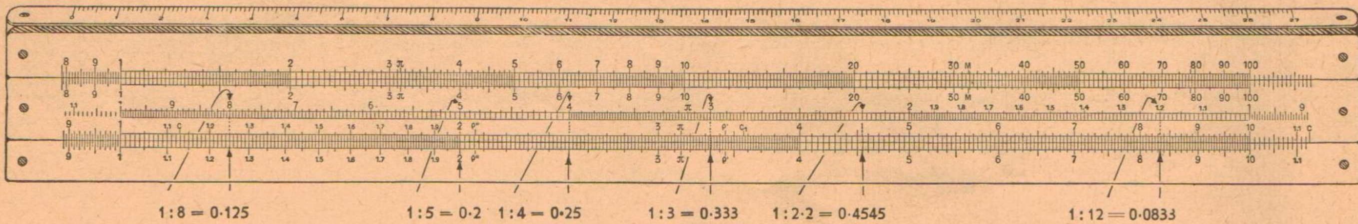


Fig. 9

2. To find 1 ÷ a^2 move the cursor to a on scale **CI** and read above it on **B** the result.

E x a m p l e, Fig. 10a: **1 ÷ $2{\cdot}44^2$ = 0·168.**

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

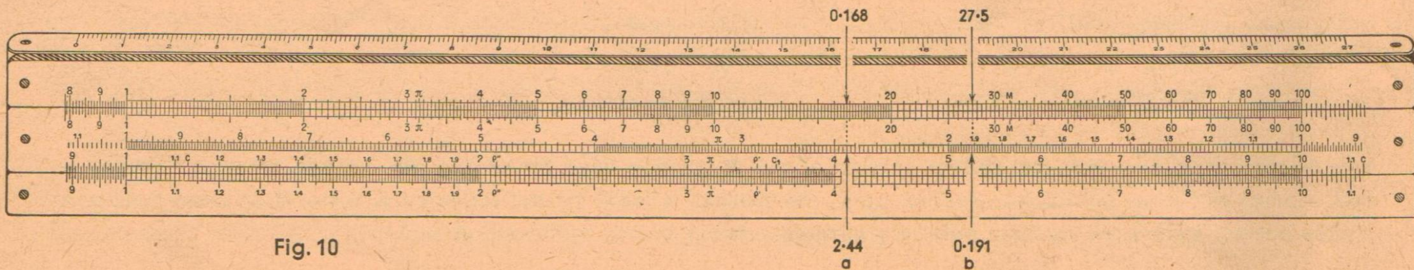


Fig. 10

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

Example, Fig. 10b: $1 \div \sqrt{27{\cdot}5} = 0{\cdot}191$.

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 **CI** and the answer will be found under the cursor line on scale **K.**

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 **K** and read the answer under the cursor line on **CI.**

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 **CI** respectively, moves the cursor to the third factor on **C** and reads below it on **D,** the final product.

Example, Fig. 11: $0{\cdot}66 \times 20{\cdot}25 \times 2{\cdot}38 = 31{\cdot}8$.

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

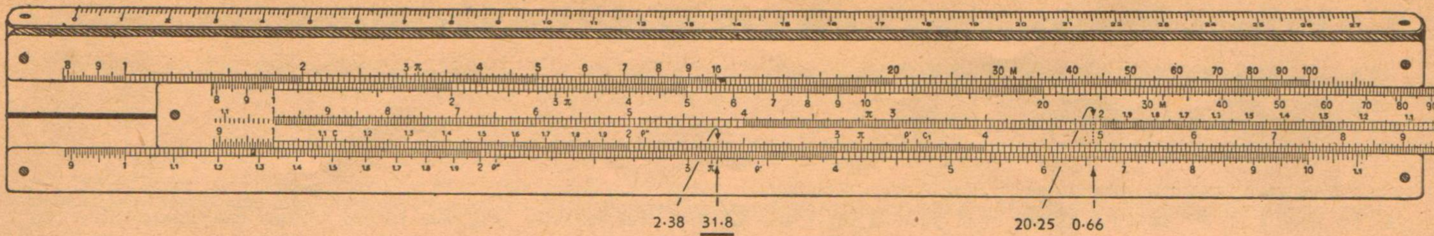


Fig. 11

In doing this it is occasionally necessary to move the slide over.

Example: $6{\cdot}05 \times 3{\cdot}24 \times 7{\cdot}15 = 140{\cdot}2$.

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 **CI**, then shift the cursor to the dividend on scale **D** and find the answer above it on **C**.

Example: $\frac{44}{4{\cdot}85 \times 3{\cdot}66} = 2{\cdot}48$.

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

Instructions for the Use of the Cursor (Slide Rules Nos. 1/87, 111/87, 4/87, 1/98, 111/98, 4/98)

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

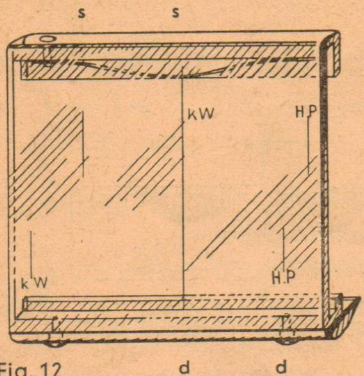


Fig. 12

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

   Set the centre or the lower right hand cursor line over the diameter, 3·2 inches, on the lowest scale **D**, and read on the upper scale, **A**, under the adjacent cursor line 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.

   Example: How many Watts are 48 HP?

   Set the cursor line "HP" over 48 on scale **A.** Under the cursor line "kW" 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 "kW" will be found 35,810 Watts on scale **D.**

Cursors for 1/92 are fitted with 3 lines only, (d and s), for the calculation of a circular cross section from a given diameter.

Cursors for 1/60 have only one line for general calculations.

Instructions for the Use of the Additional Scales

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.

Example, Fig. 13: sin 32° = 0·53.

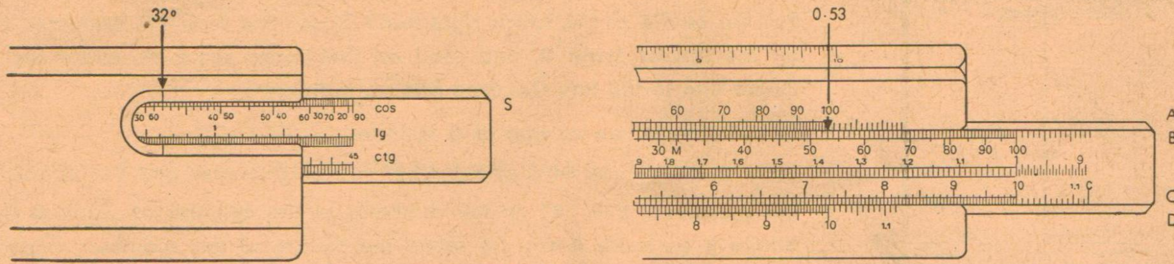


Fig. 13

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, 111/87) the **S**-scale is used with the lower scales and reading on scale **C** must be divided by 10.

Example, Fig. 14: tan 7° 40′ = 0·1346.

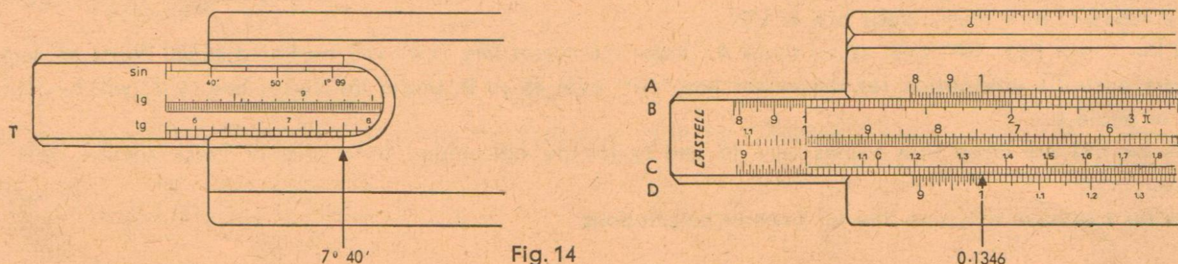


Fig. 14

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. Cotangents will also be found on scale **CI** 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 these cases the procedure is somewhat different, but it should be readily understood from the following example.

Example, Fig. 15a: 7° 40′ = 0·1346.

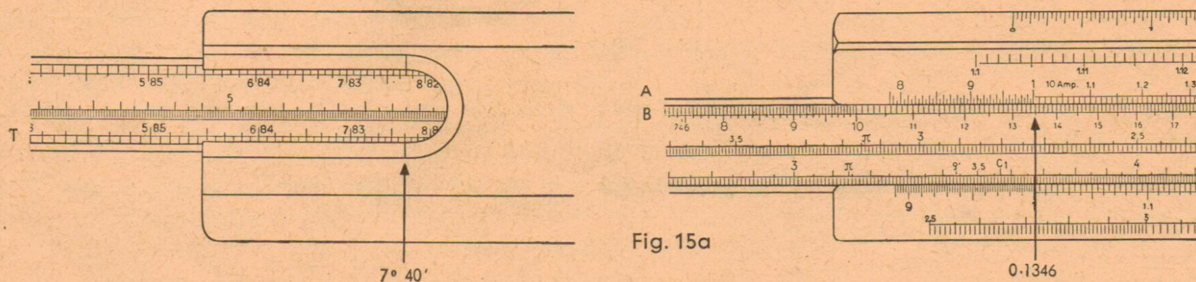


Fig. 15a

This setting is made as in Example 14, but the reading is on scale **B** under 1 on **A**. It must be divided by 100.

Rules No. 1/87, 111/87 and 4/87 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.

Example, Fig. 15b: Sin 3° 38′ or tan 3° 38′ = 0·0634.

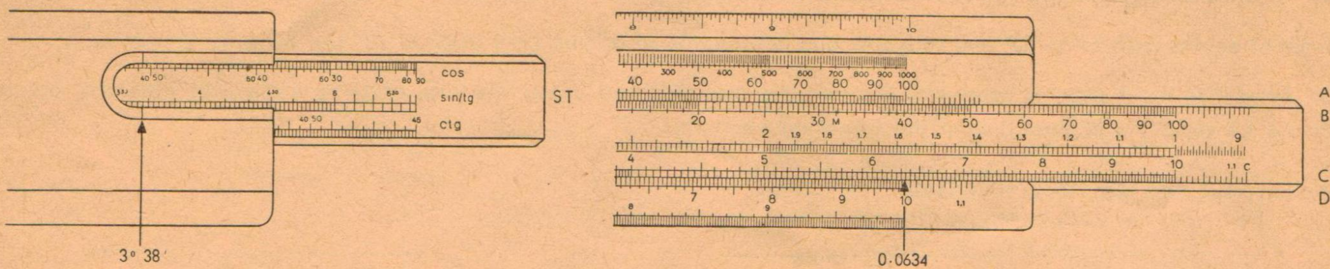


Fig. 15b

Set the angle 3° 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 a = sin (90°—a); also tangents of angles over 45° are found from cot a = tan (90°—a).

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′ ≈ tan 17′ ≈ arc 17′ = 0·00495.

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

Example: Sin 43″ ≈ tan 43″ ≈ arc 43″ = 0·0002085.

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^d to the quadrant), the same graduation (between 6·3 and 6·4 on **C**) is used for centesimal minutes and seconds.

Example: Sin $0{\cdot}17^d$ ≈ tan $0{\cdot}17^d$ ≈ arc $0{\cdot}17^d$ = 0·00267.
Sin $0{\cdot}0040^d$ ≈ tan $0{\cdot}0040^d$ ≈ arc $0{\cdot}0040^d$ = 0·0000628.

The Mantissa Scale L

Scale L on Nos. 1/60, 1/92, 1/98, 4/98, 111/98

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. 16: log. 1·35 = 0·1303; log 13·5 = 1·1303.

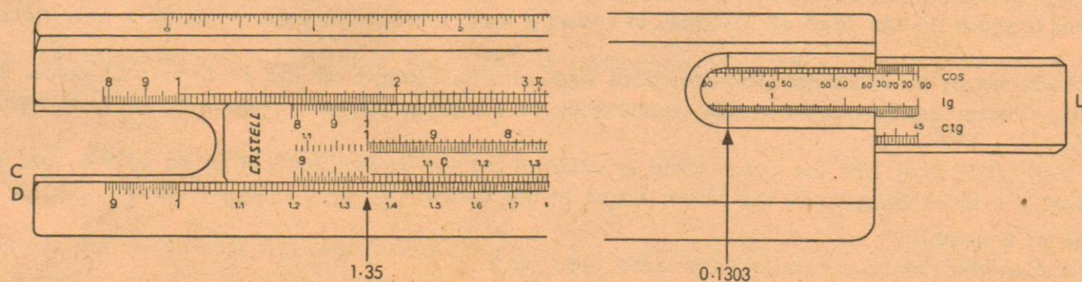


Fig. 16

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.

Scale L on Nos. 1/87, 111/87, 4/87

On rules with **S-T** divisions, the scale of logarithms is on the **face of the rule.** This scale is read with the help of the cursor.

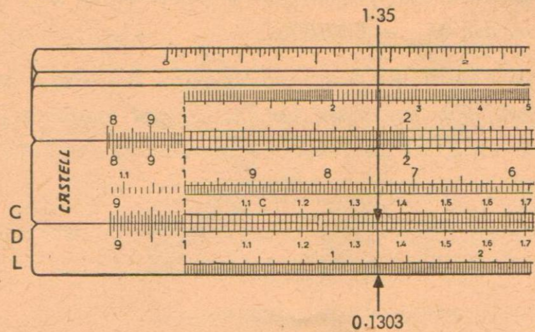


Fig. 17

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

The Cube Scale K

For the calculation of cubes and cube roots our slide rules are provided with a cube scale, **K**, 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 **K** is made up of three similar portions, each one third the length of the **D**, **C** and **CI scale.** Scale **K** is so placed that each number on **D** is in line with its cube on **K**. The three portions of scale **K** run from 1 to 10, 10 to 100, and 100 to 1,000.

On Rules 1/92, 1/98, 111/98 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.

The cursor is put over the number on **D** and the cube read on **K.**

Example, Fig. 18a: $1{\cdot}67^3 = 4{\cdot}66$.

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

Example, Fig. 18b: $2{\cdot}34^3 = 12{\cdot}8$.

Cube Root

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

Example, Fig. 18d: $\sqrt[3]{3{\cdot}65} = 1{\cdot}54$.

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

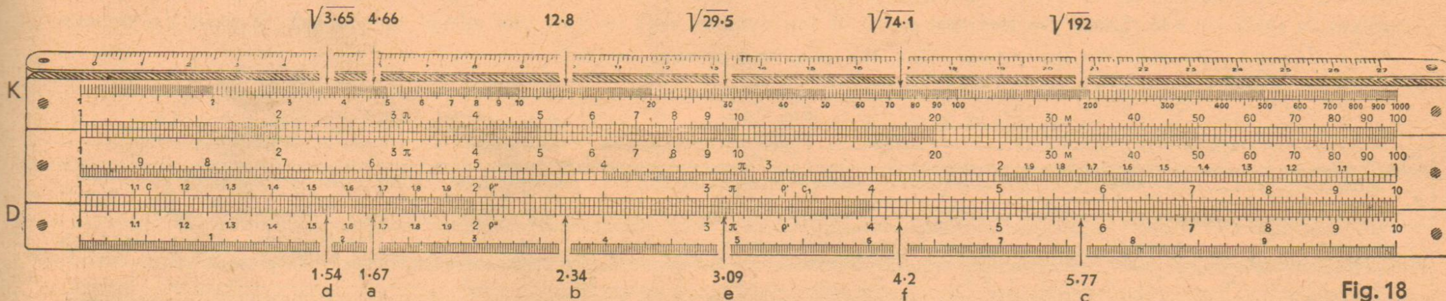


Fig. 18

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

Example, Fig. 18e: $\sqrt[3]{29{\cdot}5} = 3{\cdot}09$. Example, Fig. 18f: $\sqrt[3]{74{\cdot}1} = 4{\cdot}2$.

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

Example, Fig. 18c: $\sqrt[3]{192} = 5{\cdot}77$.

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.

E x a m p l e , Fig. 18d: $\sqrt[3]{3650} = 15{\cdot}4$.

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. 18a: $16{\cdot}7^3 = 4{,}660$.

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.

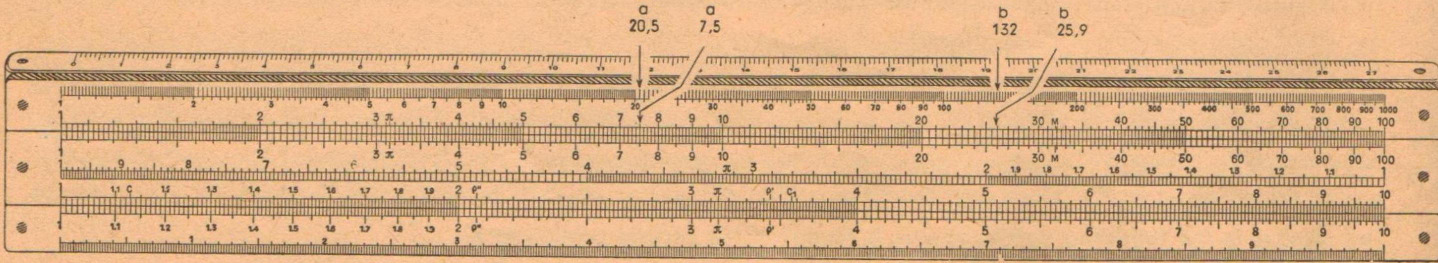


Fig. 19

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

E x a m p l e , Fig. 19a: $7{\cdot}5^{\frac{3}{2}} = 20{\cdot}5$.

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

E x a m p l e , Fig. 19b: $132^{\frac{2}{3}} = 25{\cdot}9$.

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.

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.
E x a m p l e , Fig. 20a: 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.

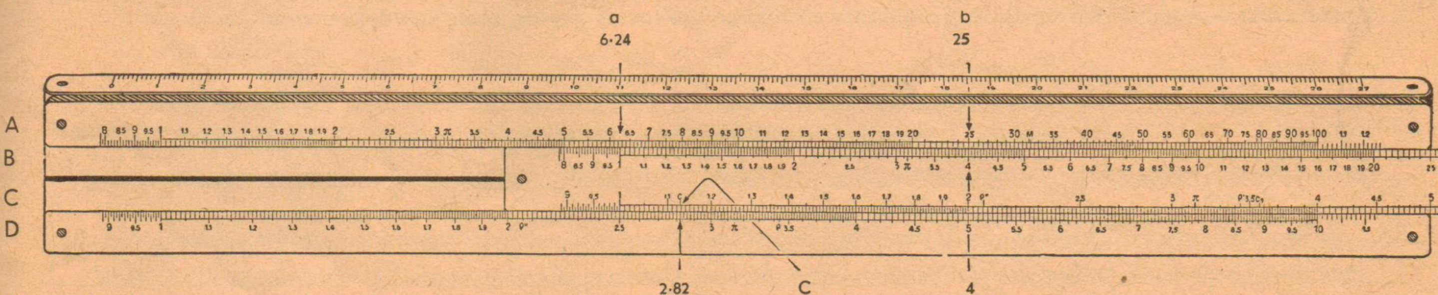


Fig. 20

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.**
E x a m p l e , Fig. 20b: If the height of the cylinder is 4 inch. the contents will be found = 25 cub. inch.

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 $1 \div \pi$.

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.

The log-log scale (Nos. 1/92, 1/98, 111/98, 4/98)

The log-log scale begins in the left top corner with 1·1 and extends to 3·2 (**LL_2**), 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_3**). 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

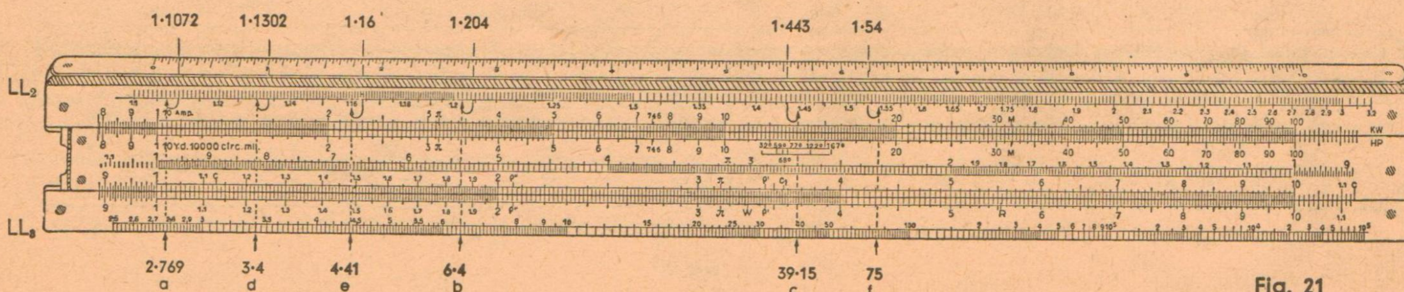


Fig. 21

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 (**LL₃**) stands on the upper log-log scale (**LL₂**) 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 (**LL₃**).

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

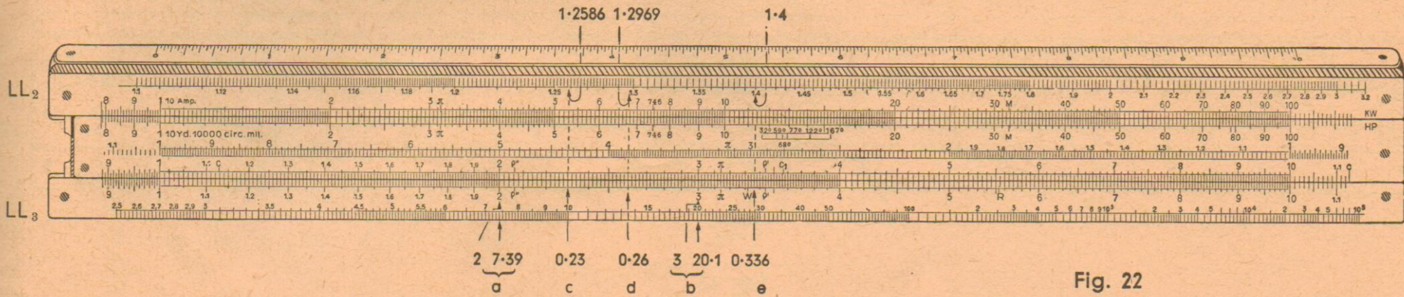


Fig. 22

4. Over every number **n** on the lower scale (**D**) stands $e^{\frac{n}{10}}$ on the upper log-log-scale (**LL₂**).

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 (0·2) and the procedure in paragraph 4 follows. If the exponent is a fraction, scale **CI** 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.

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

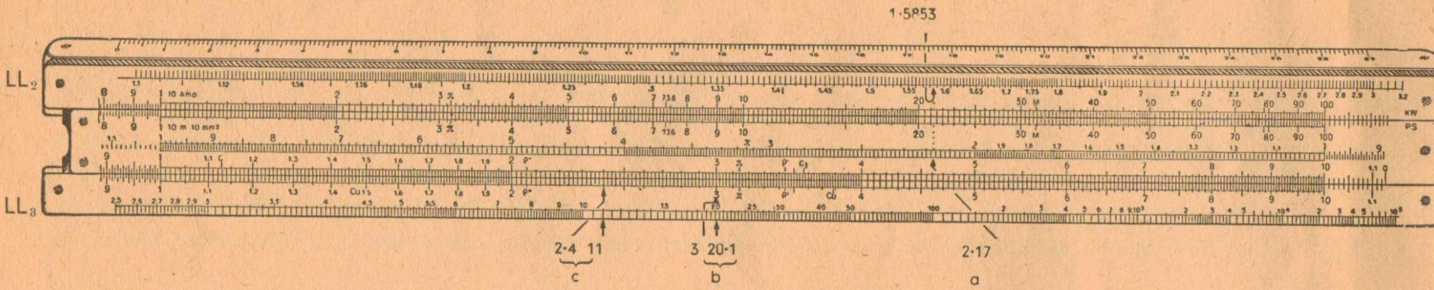


Fig. 23

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 **CI.**

E x a m p l e : $\sqrt[y]{e} = 1{\cdot}485, \; y = 2{\cdot}529$ (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 ($\log_e$).

E x a m p l e : $\text{Log}_e\, 94 = 4{\cdot}54$ (Fig. 24b) $\log_e 1{\cdot}87 = 0{\cdot}626$ (Fig. 24c).

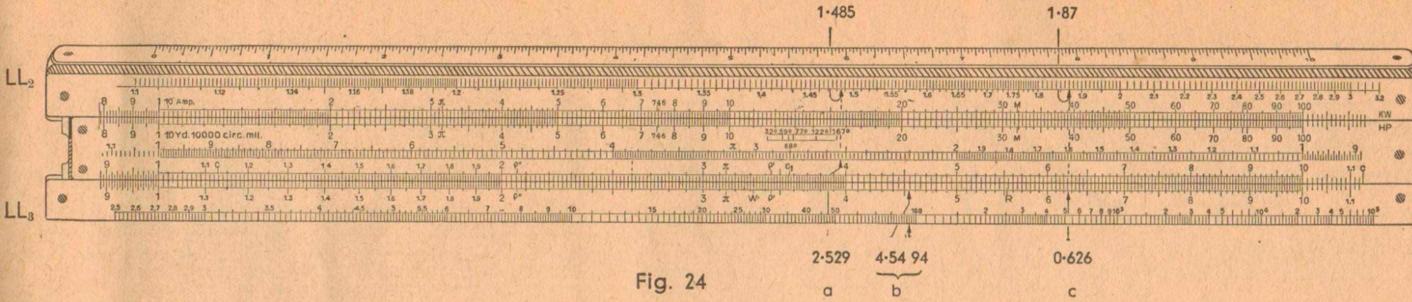


Fig. 24

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.

E x a m p l e , Fig. 25: $1{\cdot}277^{2{\cdot}22} = 1{\cdot}72$.

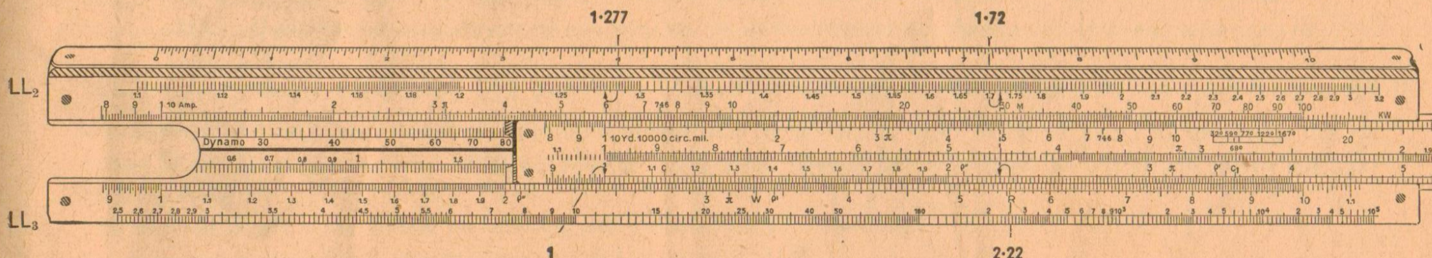


Fig. 25

With the cursor line, set 1 on scale **C** under 1·277 on scale $\mathbf{LL_2}$ and over 2·22 on **C** read 1·72, the required answer, on $\mathbf{LL_2}$ (Fig. 25).

E x a m p l e, Fig. 26: $11{\cdot}5^{2{\cdot}53} = 483$.

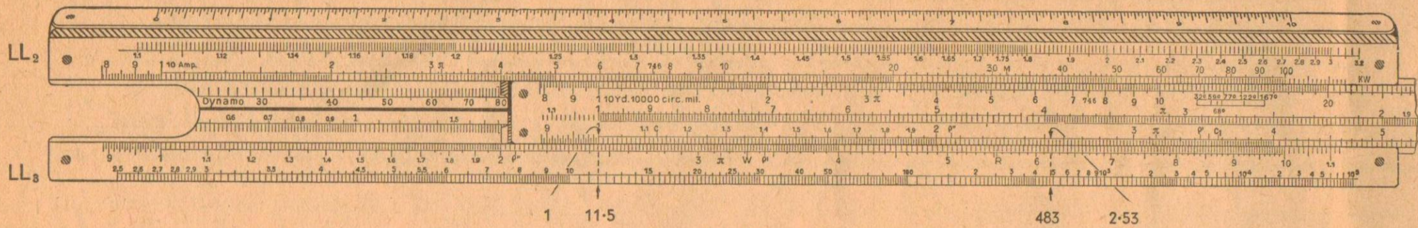


Fig. 26

In this case one has to set and read off on the lower log-log- scale (**LL_3**).
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 **LL_2** to **LL_3**.

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**.

Additional Scales of Slide Rules "Electro"

Temperature-Resistance Scale for Copper Wire.

On the slide, just to the right of the centre, will be found a short scale marked in degrees Fahrenheit. This scale which is used in combination with scale **A**, permits the variation of the electrical resistance of copper wires to be compared.

When the resistance of a wire at any of the marked temperatures is known, the resistance at another temperature may be found by placing the known temperature on the temperature scale in line with the known resistance on **A** and reading the required resistance on **A** over the corresponding temperature graduation.

Example: The resistance of a copper wire is 20 ohms at 59° F., find its resistance at 32° and 77°.

Set 59° on the temperature scale in line with 20 ohms on **A** and, with the aid of the cursor, read 18·8 ohms and 20·8 ohms respectively on **A** over 32° and 77°.

Example: A coil has a resistance of 30 ohms at 60° F., find its resistance at 100°.

Place the cursor line over 30 ohms on **A**, set the slide so that 59° on the temperature scale is just to the left of the cursor line, move the cursor over 100° (almost exactly midway between 77° and 122°) and read 32·7 ohms.

The graduations on this scale are the Fahrenheit equivalents of 0°, 15°, 20°, 25°, 50° and 75° Centigrade.

The Efficiency Scale on Castell 1/98 and 4/98. **(Geroplast Slide Rule 111/98 see page 36)**

It is assumed that either direct current or inductionless alternating current is being dealt with. The upper of the two scales in the base of the rule, displayed when the slide is moved, serves to calculate the efficiency of dynamos and motors (scale W).

The left half of the scale serves for working out the efficiency of dynamos.

It carries out automatically the division by 746 (746 Watt = 1 HP).

Attention is called to the fact that the Rules No. 1/98, 4/98, 111/98, 1/87, 4/87 and 111/87 are provided with the special cursor, which gives the conversion of Watts into HP and of diameter into sectional area without movement of the slide. (P. 15)

Example, Fig. 27: Calculate the efficiency of a dynamo giving 90 KW with 136 HP.

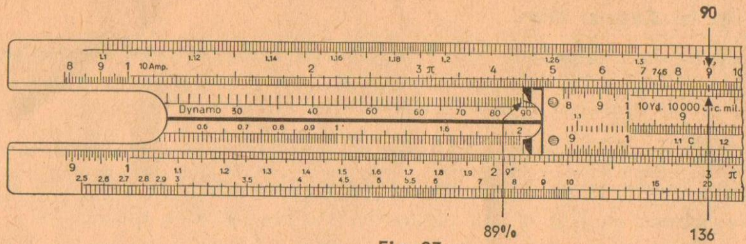


Fig. 27

Set 90 on the KW scale and 136 on the HP scale against each other. The indicator then shows on the dynamo scale 89% efficiency (Fig. 27).

Example: What electrical output can be obtained with 30 HP from a dynamo of 88% efficiency?

Set the indicator to 88% on the dynamo scale, find the number 30 on the HP scale and find above it the answer 19·7 KW.

If the result in the case before you is not satisfactory, the rule will provide in the above setting a table, from which, for every HP transmitted to the dynamo shaft, can be read off the electrical output delivered.

The right half of the scale W serves for the calculation of the efficiency of motors.

Example: Calculate the efficiency of a motor with 17·1 KW which delivers 20 HP.

Set the two numbers on the HP and KW scales respectively against each other, care being taken that the indicator actually does appear on the **Motor** scale (**right** half). Answer 87%.

Example: What power does a motor of 80% efficiency deliver with 500 Volts and 12 amp. (i. e. 6 KW)?

Move the indicator to 80% on the motor scale, find the number 6 on the KW scale, and below it 6·45 HP.

Pressure drop scale on Castell 1/98 and 4/98. **(Geroplast Slide Rule 111/98 see page 36)**

The drop in pressure in a conductor is read on the lower red figured scale in the groove.

The **V**-scale, giving the loss of potential in copper conductors on direct current circuits, or alternating of unity power factor, lies parallel to the efficiency scale, thus conforming to the colour of the index marks relating to this scale on **A** and **B**.

The marks, "10 Amp.", "10 yd", and "10,000 circ-mil" on the face of the rule and slide mean that 1 on **A** must be read as 10 amperes, and 1 on **B** as 10 yards and 10,000 circular mils when using the voltage drop scale. From this it will be seen that current is taken on **A**, and length and cross-section are taken on **B**. The voltage drop scale is based on the formula $e = \frac{I \times L}{c \times a}$;

where I = current in amperes
L = total length of conductor in yards,
c = 0·0327 ohm, conductivity of copper (mil yard) at 60° F.
a = area of cross-section of conductor in circular mils.

In using the scale, the current and the length of conductor are multiplied together on the **A** and **B** scales, the area of cross-section of the conductor on **B** is brought to the product of these two on scale **A**, and the voltage is read against the metal pointer on the red scale **V**. The **V**-scale is so graduated that division by c is not necessary.

To find the area of cross-section in circular mils, it is only necessary to square the diameter in mils - i. e., in thousandths of an inch. For instance, a wire of diameter 0·128 inches, or 128 mils, is $128 \times 128 = 16{,}400$ circular mils in area.

Example, Fig. 28: Determine the voltage drop across the ends of a copper conductor 500 yards long and 41,000 circular mils in area when the current is 12·9 amperes.

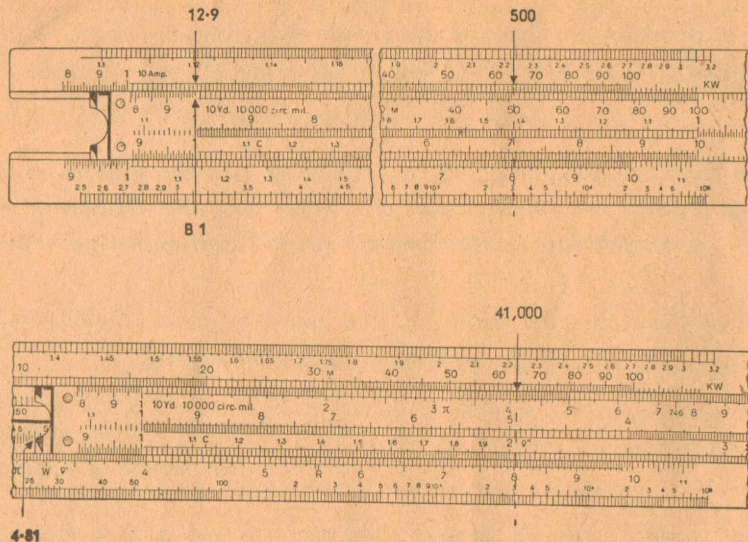


Fig. 28

Set the left hand index of **B** to 12·9 amp. on **A** (taking the left hand index of **A** as 10 amp.), move the cursor over 500 yards on **B** (the left hand index of **B** being 10 yards, 500 yards will be on the graduation 50), bring 41,000 circular mils on the left hand **B** scale under the cursor, and read 4·81 volts against the pointer on the voltage drop scale.

The voltage drop scale gives answers with the decimal point correctly placed so long as the current, length, and sectional-area of the conductor are of such size that the left hand indices can be taken as 10 amperes, 10 yards, and 10,000 circular mils. When, however, one or more of the quantities is outside these limits the decimal points may be moved. For instance, to find the voltage required for a current of 5 amperes flowing through 2,000 yards of a copper wire which is 0·040 inch in diameter, take 50 amperes, 200 yards, 160,000 circular mils instead of 1,600. The equation is as follows:

$$e = \frac{50 \times 10^{-1} \times 200 \times 10}{c \times 160{,}000 \times 10^{-2}} = \frac{50 \times 200}{c \times 160{,}000} \times 100.$$

Set 1 on **B** to 50 amperes on **A**, move the cursor over 200 yards on **B**, bring 160,000 circular mils on **B** under the cursor, and read 1·91 volts against the metal pointer. This must be multiplied by 100, and, therefore the answer is 191 volts.

The adjustments of the decimal points, both before and after calculating, can usually be done mentally.

E x a m p l e : Find the voltage drop in a 4,000 yards tramway trolley wire which has a sectional area of 90,000 circular mils. The current is 30 amperes (answer = 40·8 volts).

Should the pressure obtained be too high, set the pointer to the permissible drop, without shifting the cursor, and read the required sectional-area of conductor under the cursor line. For instance, were the potential difference to be limited to 35 volts in the last example, set the pointer to 35 volts (3·5) on scale **V** and read 105,000 circular mils on **B** under the cursor line. This is the sectional-area of a wire that will carry 30 amperes with a loss of 35 volts. The square root of 105,000 gives the required diameter 324 mils, or 0·324 inches.

If the pointer be set to permissible voltage drop (say 35 volts) on scale **V** and the cursor be put over the given sectional-area of conductor (say 105,000 circular mils) on **B**, then if 1 on **B** be brought to any selected current on **A**, under the cursor line will be found the corresponding conductor length. Or if any conductor length be brought under the cursor line, the corresponding current will be found on **A** over the left hand index of **B**. This may be more conveniently arranged in the form of a table, when the slide is reversed so that 1 on **B** is under the cursor line. Then the conductor length and corresponding currents coincide on **B** and **A.**

Examples: 40 amperes and 3,000 yards, 20 amperes and 6,000 yards,
50 amperes and 2,400 yards, 25 amperes and 4,800 yards.

Pressure drop scale and efficiency scale on slide rule No. 111/98

With the slide rule No. 111/98 the efficiency and pressure drop scales are found on the lower end of the face of the rule. Calculations involving these scales are carried out as with the slide rule No. 1/98, the only difference being that in reading and setting values on the motor, dynamo or voltage scales the cursor, set to **C** 1 or **C** 10, is used.

Examples: Calculate the efficiency of a dynamo giving 16·4 kW with 25 HP.

Set **A** 1·64 (16·4 kW) and **B** 25 (25 HP) against one another and the cursor to **C** 10. The latter then shows on the dynamo scale an efficiency of 88%.

What electrical output can be obtained with 30 HP from a dynamo of 88% efficiency?
Set **C** 1, with the aid of the cursor, over 88% on the dynamo scale, then cursor to **B** 3 (30 HP) and find the result 19·7 kW above it on the **A** scale.

Calculate the pressure drop in a plain copper conductor of 500 yards length with a cross section of 41,000 circular mils and 12·9 amperes.

Set **B** 1 under **A** 1·29 (12·9 amperes), then the cursor to **B** 5 (500 yards), then **B** 41 (41,000 circular mils) under the indicator and then the latter to **C** 10. Find the result 4·81 volts on the voltage scale.

Instruction for the Use of Marks W (for Weight) and R (for Electrical Resistance at 60° F.) of Copper Wires.

Set the length of a conductor on the scale **B** above the mark **W** and you will find above the diameter of the wire on scale **D** the weight of the conductor on scale **B.**

Example, Fig. 29: Set the length, 1,340 yards, on **B** over the mark **W** and read the weight, 3·94 lbs., on **B** over the diameter, 0·018 inch (18 mils), on scale **D.**

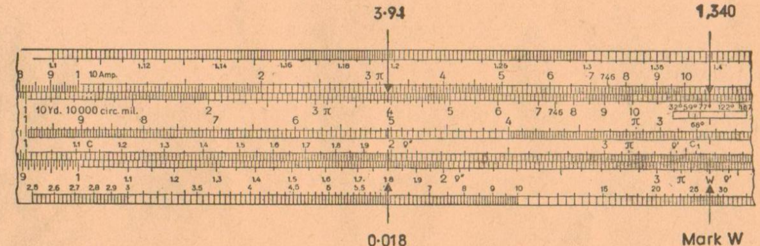


Fig. 29

Example: Set the length, **1,340** yards, on **B** over the diameter, 0·036 inch (36 mils), on **D** and read the resistance, 31·6 ohms, over the mark **R** on **B.** (Corresponds to the B. E. S. A. standard for annealed copper.)

These 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** (1/701 e.) is recommended; this contains **numerous examples, with figures,** furnishing an excellent introduction to the practical application of the Calculating Rule.

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