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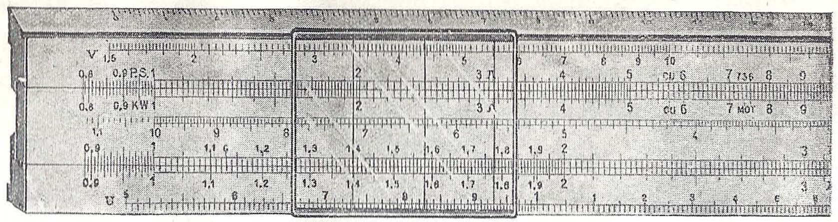
Practical Instructions

for the use of the

NESTLER

Slide Rules No. 37 and 37a

"Electro"



N° AE 2/37

THE SLIDE RULE IN ELECTROTECHNICS

The slide rule is the most appropriate calculating instrument in electrical engineering.

We hope to show on the following pages, how rapidly and easily we can work with it.

The bases of these calculations, i. e. natural constants and readings of results, are such that the precision given by the scales of the slide rule (3—4 decimal places) will be sufficient in every case, except perhaps in that of measurements of highest precision.

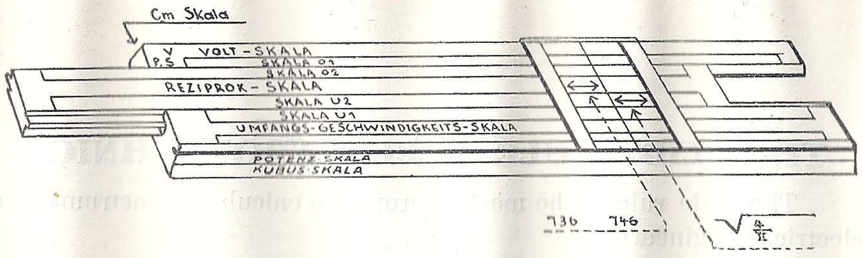
If for instance the conductibility of the copper is modified under the influence of temperature and by eventual alloys in such a low degree, it would be quite useless to calculate with logarithm tables to many places, the accuracy of the results could not be guaranteed and would only be a hindrance.

The slide rule rounds up the results to within the limit of practical requirements and we suggest that our readers might examine the given examples also in this respect.

In this leaflet we only give the instructions for the use of the slide rule without explaining the underlying mathematical principles. Anyone who is interested in the theory and would like to know the bases of construction of the scales and the mathematical principles should read the booklet.

The logarithmical Slide Rule and its Use
edited by us.

In this booklet the reader will also find the procedures which allow more accurate results to be obtained if these are specifically required.



Description of the scales

As shown by the above drawing, the slide rule No. 37 has the following scales:

On the bevel a millimetre scale, which may also be employed as a drawing scale.

On the face 1. A scale V for rapid calculation of tension losses in copper wires. Copper in coils has at 20° the specific resistance $\varrho_{20} = 0.175$ and the conductibility $\varkappa = \frac{1}{\varrho_{20}} = 57{,}2$. Scale V is constructed to base of these values.

2. A scale in two logarithmic units bearing the mark *P. S.*, which we always give in the following instruction as O_1 in order to maintain uniformity with our other leaflets.

3. An identical scale on the slide marked *kW* but mentioned in the following pages as O_2.

4. A scale of the reciprocal values *R* in the midst of the slide. In order to avoid confusion, same is engraved in red. It contains one logarithmic unit.

5. A scale at the lower edge of the slide, representing a logarithmic unit of 25 cm having the designation of U_2

6. A scale identical with the latter at the lower edge of the stock, designation U_1.

7. A scale *"U"* at the lower edge of the stock for calculating the peripherical velocities. It is divided as U_1 but displaced against this scale by the value of $\frac{\pi}{6} = 0.5236$, this number consequently corresponds with *"1" of* U_1.

On the vertical edge of the stock there are:—

1.) a scale of the *log. log* or scale of powers, designation *"P"*. It reaches from 1,08 up to 100000.

2.) A scale of the cubes *"K"*, corresponding to scale U_1.

On the back of the slide we have:—

1.) a scale *"S"* of the values of the sines,

2.) a combined scale of the functions of sines and tangents of small angles *(S & T)*

3.) a scale of the tangents *(T)*.

On the back of the stock we have a table of constants consistently used in electrotechnics.

Description of the cursor

The slide rule is provided with a cursor which has three hair lines engraved on the under side of the glass in order to allow very exact reading of the results.

The cursor can be supplied with symmetrical or asymmetrical spacing of thé hair lines. The middle hair line is for setting the values and for reading the results of multiplications, squares and square roots. It is also made use of for calculations by means of scales *"V" "P" "U"* and *"K"*. The cursor with symmetric spacing of the right and left lateral lines is for determining the areas of circles and vice versa, whilst that with asymmetric spacing of the hair lines, the combination of middle and left line is for transformation of *PS* in *kW* and inversely.

Reading of the scales

The difficulties for the beginner in reading the values of the scales exactly are soon overcome by continued exercise.

We think it useful to give an exact description of the scales:

U_1 and U_2 may be considered as having three sections as 1—2, 2—4 and 4—10. In the section 1—2 the figures are 1.0, 1.1, 1.2, ... 1.9, 2. The distance between any of these two figures has 10 secondary divisions, which thus represent the values of 1.00, 1.01, 1.02 . . . . . 1.98, 1.99, 2.00.

In the section from 2—4 the principal division lines have the figures of 2, 3, 4 and each principal interval has 10 secondary divisions, representing thus 2.0, 2.1, 2.2 . . . . 3.9 4.0.

Between each pair of dividing lines we have 5 secondary lines, thus we can set and read 2.00, 2.02, 2.04, ... 3.96, 3.98, 4. In the section from 4 to 10 the figures are 4, 5, 6 . . . . 9, 10. Between each pair of figures there are 10 secondary divisions which are bisected. Thus we have here direct readings of the values of 4.0, 4.05, 4.10, 4.15, ... 9.90, 9.95, 10.

Scale *"U"* has the same distances and figures, only its initial lines begin by 5. The scale *R* of the reciprocal values as well is divided in identical manner, only it runs from right to left. Scales O_1 and O_2 (PS and kW) have the following division marks:—

a) 1,00, 1,02, 1,04 . . ., 2,00, b) 2,00, 2,05, 2,10 . . ., 4,90, 4,95, 5,00;
c) 5,0, 5,1, 5,2 . . ., 9,8, 9,9 10,0.

In the second half of scales O_1 and O_2 the secondary division lines are the same, only the figures have added a zero. The same holds good for scale "V", wich begins with 1.5.

A calculator who understands the meaning of the division lines exactly, will soon be in a position to set and to rapidly read the values and the results. For exercise, set the middle cursor line on the values of 1.732, 2.33, 4.06, 9.52 etc. making use for similar exercises also of the scale O_1.

With the scales "K" and "P" spacing of the division lines become somewhat narrow towards the right end. Determination of its values will cause as little difficulties as that of the trigonomatrical scales on the back of the slide.

Gaugepoints on the scales

Values which occur frequently in practical computations, are marked on the scales by special lines and letters. This makes setting and reading easy.

On O_1 and O_2 we have: —

π = *3.142* for calculations in connection with areas of circles.

Cu = *57.2* for the conductibility of copper,

MOT = *736* for the conversion of the PS in kW (1 PS = 0.736 kW)

Dyn = 736 for the conversion of the kW in PS (1 kW = 1.36 PS) on O_1 only.

on O_2 only: Al = 35 for the conductibility of aluminium.

$\frac{\pi}{4}$ = *0,7854* for calculations in connections with circles.

On U_1 and U_2 we have:

$c = \sqrt{\frac{4}{\pi}} = 1{,}128$ for determining the area of circles

$\pi = 3{,}142$

$\sqrt{\ } = \sqrt{2g} = 4{,}43$ for kinetic calculations.

Cu = 57.2, *736* see above.

Definite value of series of numbers.

In the values of 1.57, 15.7, 157 . . . . 0,157, 0,0157, etc., we have the same sequence of figures, but the absolute value differs as a consequence of the different position of the decimal point. The slide rule only gives as the result a sequence of numbers and not the absolute value. For instance we have on O_1 the value of $\frac{\pi}{4} = 0.785$

exactly where the scale shows 78.5. At first sight, this may seem inconvenient, but really this is not particularly important, as the following lines will show.

1. The Valuation

A copper sheet is $l = 75.2$ cm long, $b = 5.8$ cm broad and $d = 0{,}3$ cm thick. Determine its weight, if its specific gravity is $\gamma = 8.9\,g$ cm³.

Solution: $W = l \times b \times d \times \gamma = 75{,}2 \times 5{,}8 \times 0{,}3 \times 8{,}9$ g. As we shall learn later, the slide rule gives us the sequence of numbers: 1164.

Rounding up the values and checking by approximation, we get $W \approx 70 \times 6 \times \frac{1}{3} \times 10 \approx 1400$ g. The exact value must therefore be 1164 g and not 116.4 or 11640 grm.

In practical computation, especially with problems in series, we have almost always the absolute value of the result. If, for instance, a copper wire has a resistance of 52 Ω at a temperature of *20° C*, the slide rule gives the sequence of figures *of 540* for 30° and this of course can mean only *54* and not *5.4* or *540 Ω*.

2. Computing with powers of ten

Be $10 = 10^1$, $100 = 10^2$, $1000 = 10^3$ and so on, further $1 = 10^0$, $0{,}1 = 10^{-1}$, $0{,}01 = 10^{-2}$, $0.001 = 10^{-3}$. Each number can be written as a product, of which one factor is between 1 and 10 whilst the other is to a power of 10. Powers are multiplied by adding their indices, they are divided by subtracting their indices. The number of places of a product or the quotient of two numbers, each being between 1 and 10 can easily been estimated. For instance, the cubic contents of a room are given as $72{,}4^3\,m$, or in dm³, 72400. The specific gravity of the air with a reading of *760 mm* on the barometric scale at *20° C* is *0.001 205 kg*, therefore the weight of the air contained in this room = W = 72400 × 0.001205 kg. $W = 7.24 \times 10^4 \times 1.205 \times 10^{-3} = 7.24 \times 1.205 \times 10^1 \approx 9 \times 10 = 90$ kg. The slide rule gives the sequence of figures 872; the exact weight therefore is *87.2 kilos* approximately 1 ³/₄ cwts.

A balloon has the contents of *1530 m³* and its buoyancy is 1240kg. How many kilos can be lifted by 1 dm³?

Solution: The volume is *1530000 dm³* when converted into dm³

$$\frac{1240}{1530000}\ \text{kg} = \frac{1.24 \times 10^3}{1.53 \times 10^6}\ \text{kg};\quad \frac{1.24}{1.53} = 0.810,\ x = 0.810 \times 10^{3-6} = 0.810 \times 10^{-3} = 0.000810\ \text{kg/dm}^3.$$

Multiplication

If considering *a* and *b* as numbers within the limits of 1 and 10 which does not mean any restriction for the general rule, and we want to form the product $x = a \times b$. For this purpose we set middle cursor line coincidental with "a" on U_1 then set initial line "*1*" of U_2 coincidental to cursor line. Cursor is then moved along until its middle line covers number "b". When coincidental to this number, we read on U_1 the result "x".

Example 1. Practise the above described procedure by examples which can easily be proved by mental calulation, such as 2×3, 2×4, $3{,}5 \times 2$ etc.

Transposing of the slide

For multiplication and division with the slide rule, numbers 1 and 10 are of equal suitability. When it is required, we can transpose the slide i. e. replace the 1 by 10 or inversely. We fix the position of "*1*" of U_2 by the curcor line and then we move the slide from the right to the left, until middle cursor line coincides with *10* on U_2. It is also easy to execute the inverse operation. The red continuation scales at the right and left end of the scales often make transpositions unnecessary.

Example 2. We have to obtain the products of 3×2, 3×3, 3×4, using the slide rule.

Solution: Setting 1 on scale U_2 coincidental with figure 3 on scale U_1, we have opposite figure 2 (on U_2) the number 6 (on U_1) opposite figure 3 (on U_2) the number 9 (on U_1) but figure 4 (on U_2) has no value on scale U_1. We must therefore shift the slide by unity and thus get $3 \times 4 = 12$, $3 \times 5 = 15$, and so on.

This setting would have been chosen from the beginning, we had found by estimation that $a \times b > 10$.

As $a \times b = b \times a$, "b" could have been set on U_1 and "a" on U_2, had we stopped and examined it closely, the result read by the first setting. In the example 2, a definite number "3" has been multiplied successively by a series of others. In this case the constant number was set on U_1 and the variable factors on U_2. For such series the slide rule is especially adaptable.

Scales O_1 and O_2 result from those of U_1 and U_2, the former being reduced in the ratio of 1 : 2. The right side of the scale corresponds exactly to the left one, as we can observe by comparison with the slide scale O_2. Executing the calculations of example 2 on both scales, we state, that no shifting of the slide is required. It is recommended to give preference to the middle division line "*10*" before the lines "*1*" and "*100*".

If we have not to work with numbers having decimal places the lower scales work somewhat more precisely than the upper ones on which the distances of the division lines are narrower.

Example 3. A copper wire has the resistance $R = 9.62\ \Omega$. Throug this wire and through an ammeter flows a current, which is gradually intensified. We read on the instrument successively J=0.85, 1.23, 5.68, 7.39. 8.44 A. Determine for each case the difference of tension at the ends of the wires.

Solution: According to the law of OHM, U (difference of tension) = R (resistance) $\times$ I (Intensity). We set *10* of U_2 coincidental with *9.62* of U_1 and move

the cursor line successively to 8,5, 1,23, etc on U_2. Under the cursor line in this position we have on U successively 8.18, 11 83, 54.6, 71.1, and 81.2 *V*.

Determination of the correct decimal place is made by estimation; as $R \approx 10\ \Omega$, we have only to multiply the given intensities of current, by 10 in order to get the approximate tension loss.

Example 4. A current of the intensity of *1 A* precipitates in a solution of nickel-salt 0.3041 mg nickel during one second. Determine the quantity it will precipitate during 8 hours.

Solution: 8 hours=28800 s. 0,3041 mg=0,0000003041 kg. Calculated in the usual way we get 0.00875808 kg=8.75808 g. It is evident, that calulations of this kind are susceptible to errors in the position of the decimal point. As we know not whether the last figure in the result 0,3041 is of absolute exactitude and as we have to reckon with small differences in the intensity of the current, neither do we know if the time is given with absolute exactitude, the precision which we seem to have obtained, is only hypothetical. Calculating for instance with 0.30406 mg, 0,997 A, 28780 s. we obtain 8,72460 g. Making use of the slide rule we have: 0,3041 mg $= 3{,}04 \times 10^{-7}$ kg, $28800 = 2{,}88 \times 10^4$, $x = 3{,}04 \times 10^{-7} \times 2{,}88 \times 10^4 = 8{,}76 \times 10^{-3}$ kg $= 8{,}76$ g. As the result will suffice for practical computing, we can easily state what a tremendous amount of work is avoided by use of the slide rule.

Products with three and more factors

If $x = a \times b \times c$, we get the product of $a \times b$ as we have shown page 7. This intermediary value does not need reading, so we shift the slide until the initial or end line of U_2 is exactly coinciding with this product.

Then we set cursor line to c of U_2 and coinciding with this value, we have on U_1 the product sought, $x = a \times b \times c$. If $x = a \times b \times c \times d$, we have only to proceed in a similar way. Of course we can also make use of scales O_1 and O_2 in order to avoid transpositions of the slide rule.

Example 5. $x = 3{,}56 \times 0{,}018 \times 16{,}25 \times 124{,}5$.

Solution: Ignoring the position of the decimal point, we get for the first two factors *641,* for the first three *1041* and for x we obtain 1297. There is no need to read the intermediary results of 641 and 1041. As for the number of places, we have by approximation $x \approx 4 \times 2 \times 10^{-2} \times 2 \times 10^1 \times 1 \times 10^2 = 16 \times 10^1 = 160$. The exact value is 129.7.

Example 6. A current of *1 A* precipitates in a solution of silver *1,118* mg silver in 1 second. How much of this precious metal is obtained, if 41,5. A work during 11 hours 30 minutes?

Solution: $x = 41{,}5 \times 0{,}000001118 \times 41400$ kg $= 1{,}921$ kg $(x \approx 4 \times 10^1 \times 10^{-6} \times 4 \times 10^4 \approx 16 \times 10^{1-6+4} \approx 16 \times 10^{-1} \approx 1{,}6)$.

Example 7. Determine $1{,}06^n$, if n increases from 2 to 10.

Solution: Set 1 of U_2 opposite 1,06 of U_1. Coincidental to 1,06 of U_2 we have on U_1 $1.06 \times 1.06 = 1.06^2 = 1.1245$. Without altering the position of the slide, we set 1.124 on U_2 finding under this value on U_1 $1.06^2 = 1.191$ etc. By serial multiplication we find

n	1	2	3	4	5	6	7	7	9	10
1.06^n	1.06	1.124	1.191	1.262	1.338	1.418	1.504	1.594	1.690	1.791

Determination of the correct decimal place is made by estimation. For verification we can calculate $1{,}06^{10} = 1{,}06^5 \times 1{,}06^5$ or $1{,}06^4 \times 1{,}06^4 \times 1{,}06^2$ or the like.

Having the product 3 or more factores, an easy method for calculating is given on page 18 where the use of the reciprocal scales is explained.

Division

If we have to calculate

$$1)\ x = \frac{a}{b}$$

we set b on $U2$, opposite a on $U1$ reading x on $U1$ opposite 1 or 10 on $U2$. We can also make use of scales O_1 and O_2. In any case $\frac{a}{b} = \frac{x}{1}$, a and x being on the stock, b and 1 on the slide scale.

Determination of the correct decimal place is made by estimation or by calculating with powers of 10. We can also calculate $x = \frac{1}{b} \cdot a$ („b" ($U2$) opposite „1" ($U1$), „x" ($U1$) opposite „a" ($U2$)).

Example 8. The ends of a wire have a difference of tension of $U=220$ *Volts*. The resistance being $R=63\,\Omega$, determine the intensity of current-amperage.

Solution: $A = \frac{U}{R} = \frac{220}{63} = 349$ A.

Example 9. The initial cost of a machine is $a=35000$ $ and is supposed to work for a period of 10 years. Determine the amount of the yearly depreciation, if we have to reckon with a yearly interest of 6%.

Solution: For the depreciation we must create a fund to allow the acquisition of a new machine of equal value after $n=10$ years. Let the yearly depreciation be called r. Then we have according to the rules for calculating compound interest $\frac{r\,(q^n - 1)}{q-1} = a$, where $q=1+\frac{p}{100}$, being in our case, 1.06. Further $r = \frac{a\,(q-1)}{q^n - 1} = \frac{35000 \times 0{,}06}{1.06^{10} - 1}$. The original difficulty, namly to determine 1.06^{10} has been explained in example 7, thus we get $r = \frac{2100}{0.791} = 2655$ $.

Example 10. A copper wire 1 km long has the resistance of $R = \frac{17{,}5}{q}\,\Omega$, q the cross-sectional area, being given ie square m/m. (mm²). Determine R, q, being 0.785, 1.767, 3.142, 4.91, 7.07, 9.62, 12.56 mm² respectively.

Solution: 22.3 9.90, 5.57, 3.56, 2.475, 1.819, 1.393 Ω. Number of places $\frac{17.5}{0.785} \approx \frac{20}{1} \approx 20$, $\frac{17.5}{12.56} \approx \frac{18}{12} \approx 1{,}5$. The results vary from 22.3 to 1.393.

$$2)\ x = \frac{a \times b}{c}$$

a) Calculate $a \times b$ as explained on page 7. The result on $U1$ is not read. With the cursor line, we set c coincidental with this value and we get x on U_1 opposite 1 on $U2$. For this operation two settings of the slide are required.

b) We set $x = \frac{a \times b}{c}$ calculating a/c as per page **10**. Without moving the slide, we determine b on U_2 reading the coinciding result of x on U_1. We can also write it $\frac{a\,(U_1)}{c\,(U_2)} = \frac{x\,(U_1)}{b\,(U_2)}$. As we require only a single setting of the slide, this procedure is less complicated than the preceding one.

Example 11. If a wire has a length of 1 metre, a cross-sectional area of q *mm²* the specific resistance of the material of $\varrho\ \Omega$ mm²/m, the resistance R will be $R = \frac{\varrho \times l}{q}\ \Omega$. For the temperature of 20° we have the following table:

Material:	aluminium	lead	iron	copper	manganine	nickel	mercury	silver
ϱ	0.0286	0.21	0.099	0.0175	0.42	0.09	0.958	0.0165

Determine the resistance of a wire 145 m long and having a cross-sectional area of 1.227 mm².

As $\frac{l}{q}$ is constant in all the cases of this problem, the procedure explained under b is preferable. We obtain the following table:

Material:	aluminium	lead	iron	copper	manganine	nickel	mercury	silver
Resistance:	3.38	24.81	11.7	2.068	49.6	10.64	113.2	1.950 Ω

Estimating the number of places: $\frac{l}{q} = \frac{145}{1.227} \approx 120$, Al: $120 \times 0.03 \approx 3.6$, Pb: $120 \times 0.2 \approx 24$. etc.

$$3)\ x = \frac{a}{b\,c}$$

a) Divide $a:b$ *on* U_1, then divide further by setting c coinciding with the result of the first division. The result is read opposite the initial or end line of U_2 on U_1. We can also replace b by c and inversely.

b) Determine $b \times c$ on U_1 setting a on U_2 coincidental. Then opposite 1 or 10 of U_1 we have the value of x. ($b\,c : a = 1 : x$). on U_2.

Example 12. A copper wire 245 m long has a resistance of 2.4 Ω. Its conductibility $\left(\frac{1}{\varrho}\right)$ is $\varkappa=57.2$. What is its cross-sectional area?

Solution: $R = \frac{\varrho \times l}{q} = \frac{l}{\varkappa\, q}$, $q = \frac{l}{\varkappa R} = \frac{245}{57.2 \times 2.4} = 1.785$ mm². The gauge points engraved on the scale facilitate the calculation to a high degree. We might have made use also of the scales O_1 and O_2.

Scale V

If we prefer to calculate with the specific resistance instead of the conductibility of the copper ($\varrho = 0.0175$) thus to form $a \times \varrho$, where a given, we set 1.75 of O_2 coincidental with 1 of O_1 a is determined on O_1. Then the required product, on $U2$, coincides with it. In order not to have to frequently repeat this setting, we have had traced at the upper edge of the stock the scale V which corresponds exactly to the above described position of O_2. Moving the cursor, its line will cover the values on scales O_2 and V which correspond with one another. Setting a on O_1, we have coinciding with it, $a \times \varrho$ on V. Thus the other scales of the slide rule can be used for other calculations.

In the example 11 we have for copper $R = \frac{145 \times 0.0175}{1.227}$

Division of 145 by 1.227 is made in the usual, way using the scales O_1 and O_2. The result found on O_1 (118.2), need not be read, because under the cursor line we find directly V 2.07 Ω.

Determination of the correct decimal place is very easy, considering that for copper $a \times \varrho \approx \frac{a}{60}$.

Scale V can be made use of only in combination with scales O_1 and O_2.

Example 13. A number of copper wires have the same cross-sectional area 1 mm², the lengths are 1.25 m; 23.4 m; 308 m; 1216 m. What are their respective resistances?

Solution: $R = \frac{l \times \varrho}{2.4} = l \times \varrho$. We set the lengths on O_1 and under the cursor line in the respective position, we find on V that R=0.0219, 0.410, 5.39, 21.3 Ω.

Example 14. Taking cross sectional area of a wire as being 2.4 mm and using as in the above example. Determine the respective resistances.

Solution: $R = \frac{l \times \varrho}{2.4}$. Set 2.4 of O_1 coincidental with l of O_1. If now the lengths l are set on O_2, we have, coinciding with them the value of l. On V we read directly $\frac{l \times \varrho}{2.4}$ thus obtaining 0.00911, 0.1706, 2.25, 8.87 Ω.

The Specific resistance of copper

From a technical handbook we have the following information: At a temperature of 20°, the resistance of copper is $\varrho_{20} = 0.0178$ for conductors and 0.0175 for coils. copper for conductors must have the maximum value of $\varrho_{20} = 0.01784$. Ignited first class copper must have the value of $\varrho_{20} = 0.01724$. Even the smallest amounts of alloy can modify these values to a considerable degree.

If the temperature is not 20° but $t°$, the specific resistance is $\varrho_t = \varrho_{20} + \varrho_{20} \times a\ (t-20)$; a for copper = 0.00392. At 15° for instance copper for conductors has the specific resistance of $\varrho_{15} = 0.0178 + 0.0178 \times 0.00392\ (-5) = 0.0178 - 0.0003 = 0.0175$.

For an average of these different values, we have assumed 0.0175 the deviations for which in practical computation will be without significance. If, after calculating, we find that a more precise determination is required because of this differing value, we have only to multiply the provisional result by $\frac{\varrho}{0.0175}$ if ϱ is in the numerator, by $\frac{0.0175}{\varrho}$ if ϱ is in the denominator. If, for instance, we

wish to get the resistances of conductor copper as per example 13, the factor $\frac{0.0178}{0.0175} = \frac{178}{175}$, we get $R = 0.0223$, 0.417, 5.48, 21,7 Ω. We could have calculated right from the beginning with the exact value on O_1 and O_2 or U_1 and U_2 and without using scale V and the corresponding gauge points.

The Gauge point π

Very often multiplications or divisions occur where $\pi = 3.142$ is used. We have therefore had engraved on the scales O_1, O_2, U_1 and U_2 a corresponding gauge point. If d is the diameter of a circle or a sphere, we have for the circumference of the circle $\pi \times d$ and for its area $\frac{\pi d^2}{4}$, and for the surface area of the sphere πd^2, and for its contents $\frac{\pi d^3}{6}$.

If we have only to multiply or divide by π, it is recommended that use be made of the gauge point on one of the slide scales. If we have to form a series of products with the factor π, we set same on U_1, bringing initial or final line of U_1 coincidental with π, then successively reading the results $a_1 \pi$, $a_2 \pi$, $a_3 \pi$ . . on U_1.

If numbers a_1, a_2, a_3 have to be divided by π, we set π on U_2 coincidental with 1 or 10 on U_1, setting cursor line to a_1, a_2, a_3 respectively on U_2, having under the line in this position $\frac{a_1}{\pi}, \frac{a_2}{\pi}, \frac{a_3}{\pi}$ . . . on U_1. Here again, of course, we can also make use of O_1 and O_2 instead of U_1 and U_2.

Example 15. A coil has 100 windings. Determine the length of the wire to be used, if the radius, of a winding is alternatively 80, 85, 90, 95, 100 mm respectively.

Solution: 50.3, 53.4, 56.6, 59.7, 62.8 m.

Example 16. Some wires have the length of 250, 283, 325, 417, 500 mm respectively. Each of them is bent into a circle. Which are the respective diameters?

Solution: 79.6, 90.1, 103.5, 132.7, 159.2 mm.

Example 17. A hollow sphere of metal has a diameter d of 120 mm. It has to be plated with silver by electrolysis. It is suspended in a solution of nitrate of silver and exposed to a current of *4 A* for 6 hours Determine the thickness of silver.

Solution: The coating area of the sphere is $\pi d^2 = 14400\ \pi = 45200$ mm². As *1 A* precipitates 1.18 mg. of silver during 1 second, *4 A* yield $4 \times 6 \times 3600 \times 1.118 =$ 96 600 mg during 6 hours. The specific gravity of silver is 10.5 mg per mm³, thus the precipitated quantity of silver will be $96600 \div 10.5 = 9200$ mm³. It is spread over 45 200 mm², thus the coating of silver is $9200 \div 45200 = 0.2035$ mm thick. In order to avoid unnecessary readings, we calculate thus: $x = \frac{24 \times 3600 \times 1.118}{10.5 \times \pi \times 14400}$ $= 0.2035$. The number of places is $x = \frac{2 \times 10^1 \times 4 \times 10^3 \times 1}{10^1 \times 3 \times 10^4} \approx \frac{8}{3} \times \frac{10^4}{10^5} \approx 2.3 \times 10^{-1} \approx 0.23$.

Example 18. A Leyden jar is of cylindrical form. Its glass is $a=3$ mm thick, the external diameter D is 150 mm. The jar is covered inside and outside by a tin foil up to a height H, externally, of 250 mm. Determine the quantity of foil required.

Solution: The internal diameter is $d=D-2a=144$ mm, the internal height $h=H-a=247$ *mm.* The outer bottom coating $\frac{\pi\ D^2}{4}$ $(=\pi \times D \times D \div 4)$—17670 mm², the inner bottom coating $\frac{\pi\ d^2}{4}$ =16280 mm². The side require $\pi \cdot D \cdot H=117800$ and 111700 mm², total 263450 mm²=0,2634₅ m².

Scale U

Example 19. A pulley has a diameter d, of 0.80 m. It makes $n=310$ revolutions per minute. Determine its pheripheral velocity.

Solution: Circumference $\pi \times d$ is covered n times during one minute. The distance covered during one minnte is the peripheral velocity and is therefore $\frac{\pi \times d \times n}{60}$ m/s. In our case we have $v=\frac{\pi \times 0{,}8 \times 310}{60}=13$ m/s. For calculating we first set 6 on U_1 coincidental with this value π of U_2 and find on U_2 and coincidental with $0.8 \times 310=248$ on U_2, the value v sought, on U_1. Number of places $v \approx \frac{d \times n}{20}$.

As similar problems occur frequently, we have had traced on the stock on the under edge scale U, which corresponds exactly to the setting, just described, of scale U_2. It is recommended that investigation be made using the glass cursor. Whilst U_2 ends opposite of 1.91 of U_1, scale U is continued towards the left, so that no shifting of the slide is required, as is the case with the procedure explained above. In order to have the value of $\frac{\pi \times a}{60}$ (a being given) we set "a" on U_1 and under the cursor line, covering a, we read on U the result. In our example a is coincidental to 248 on U_1 the result 13 is being read on U. Number of places $v \approx \frac{248}{20} \approx 12.4$.

Example 20. Same problem as for examxle 19, but taking d as. 0,755 m and n as 190.

Solution: Set 10 of U_2 coincidental to 7.55 of U_1 cursor line coincidental to 1.9 of U_2 and then reading on U the value of $v=7.51$ m/s. The procedure explained earlier would prove much more complicated. Number of places $v=\frac{0{,}755 \times 190}{20} \approx 0{,}755 \times 10 \approx 7.5$ m/s.

If before making use of the scale U, we have to execute other computations, we must use scales U_1 and U_2 and not O_1 and O_2.

In angular velocity ω we denote the velocity in m/s, which has a point, which is distant 1 metre from the axis of rotation. The velocity of any point is then $v=r\,\omega$ (m/s), if r is the distance of $\frac{d}{2}$ of this point from the axis of rotation. For n revolutions per minute we

have $\omega=\frac{2\,n\,\pi}{60} \approx \frac{n}{10}$. 2 n of U_1 corresponds therefore with ω on U. We can also set the initial or final line of U_2 coincidental to 2 of U_1, then determine n on U_2 and read ω coincidental with this latter number on U.

Example 21. Examine the following table:

n	14	108	472	883	950	3000	revolutions per minute
ω	1.466	11.31	49.4	92.5	99.5	314.2	s^{-1}

Example 22. Examine the following table:

d	0.135	1.415	0.047	0.55	0.88	m
n	618	145	818	315	135	revolutions per minute
ω	64.7	15.18	85.7	33.0	14.14	s^{-1}
v	4.37	10.75	2.013	9.07	6.22	m/s

Kilowatt and horse power

A generator converts mechanical energy into electrical energy and a motor converts electrical energy in mechanical energy. The unity of output is that obtained in one second. In electrotechnics the measurement is the *kW* and in mechanical technology the measurement is *HP (1 HP = 75 kg/ms).* The output is obtained by multiplying the energy by the time (in s.) 1 PS = 0.736 kW ($\approx$ ¾ kW), 1 kW = 1.36 ($\approx$1 ⅓) PS.

For the mechanical effect we have one *kW* hour $= 1.36 \times 3600 \times 75 = 367000$ kgm. For easy transformation, we have on O_1 (PS) the gauge point *Mot 736* and *DYN (1.36)* and on U_1, U_2, and O_2 also the gauge point *Mot(736).* Coinciding *Mot(736)* on O_2 (or *kW*) with 10 of scale O_1 (or *PS*) we have on the stock scale the output in *PS* and on the slide scale under the same line of the cursor the same effect expressed in *kW.* For this reason we have had scales O_1 marked with *PS* and *kW* marked on O_2. We can also set 10 of O_2 to coincide with *Dyn* O_1, we obtain the same effect of setting as $\frac{1}{0.736}=\frac{1.36}{1}$, 1.36 PS = 1 kW.

With this position of the scales we can easily convert *PS* in *kW* and inversely. Setting and reading correspond to the marking of the upper scales.

Example 23. Convert 12.5, 43.8, 129, 236, 1360 PS in kW.

Solution: 9.20, 32.2, 95.0, 173.7, 1000 kW.

Example 24. Convert 13.9, 58.0, 144, 570, 2000 kW.

Solution: 18.9, 78.9, 195.8, 775, 2720 PS.

Example 25. Determine η, where $\eta=\frac{83\text{ kW}}{122\text{ PS}}$.

Solution: 122 PS$=\frac{122}{1.36}$kW, thus $\eta=\frac{83 \times 1.36}{122}$. Setting 83 of O_1 to coincide with 122 of O_2 corresponding with the marking of the two scales, then we have opposite 10 of O_2 on O_1 $\eta=83 \div 122=0.680$. $0{,}680 \times 1.36=0.925$.

Example 26. Determine η, where $\eta=\frac{92\text{ PS}}{82\text{ kW}}$?

Solution: Set 92 of O_1 opposite 82 of O_2, corresponding to the markings of the scales. Then set cursor line to coincide with 736 (*Mot*) on O_2 and find η=0826 on O_1.

Whether we shall set finally on *Dyn* (example 25) or on *Mot* (example 26) depends on the unity in the numerator. *PS* refers to the mechanical, *kW* to the electrical effect.

Example 27. Investigate the following table for $\eta = \frac{\text{numerator}}{\text{denominator}}$

Numerator	12 kW	4 PS	105 PS	63 kW	250 PS	900 kW
Denominator	17 PS	3 kW	92 kW	95 PS	213 kW	1600 PS
η	0,961	0,981	0,840	0,901	0,864	0,764

By a generator *(Dynamo)* mechanical energy as may be supplied for instance, by a waterfall, is transformed in electric energy. An ideal machine would yield exactly 0.736 *kW* for the energy of 1 *PS*. Owing to the loss by friction etc. the effective output is smaller. The ratio between effective output and energy required, is designated as grade of efficiency. Thus per example 25, for the energy of 122 *PS* spent, not 122×0.736 = 89.8 kW are supplied, but only 83 *kW*, $\eta = \frac{83\text{ kW}}{122\text{ PS}}$. If an electric motor receives *a kW* and if it yields *b PS* its grade of efficiency is $\frac{b\text{ PS}}{a\text{ kW}}$.

Example 28. By tests we know that the grade of efficiency of *a* dynamo is 0.925. It receives a supply of energy of 9150 kgm per second. Determine its electrical output.

Solution: 9150 kgm/s$=\frac{9150}{75}=$122 PS. The output sought is *x kW*. Then $\frac{x\text{ kW}}{122\text{ PS}} = \eta = 0{,}925$. This number is set under *Dyn* O_1, then coinciding wtih this on O_2 *kW*83 *PS* 122 on O_1 and coinciding with this value we read on scale on O_2 kW 83 PS. We have here the inverse of the problem in example 25.

Example 29. The efficiency of an electric motor is 86.5 %. Determine the values of PS, if the following energies are received by it: 8, 10, 27, 73, 147, kW.

Solution: 9.40, 11.75, 31.7, 85.8, 172.8 PS. Here we have to set η = 0.865 (O_1) opposite Mot (O_2) and the cursor line on the given values on O_2 (*kW*).

Proportions.

In electrotechnics ratios of the form $a \div b = c \div x$ often occur, *a*, *b*, *c*, being given whilst *x* is sought. For this purpose we set *b* of U_2, coincidental with *a* on U_1, sliding cursor line on *c* of U_1, reading coincidental *x* on U_2. We may also change the scales or make use of the upper scales. If for instance $3 \div 5 = 4 \div x$ we get in this way $x = 6.67$.

Example 30. Transform the expressions of 1.) $x = ab$, 2.) $x = \frac{a}{b}$, 3.)$x = \frac{ab}{c}$ for proportional calculation.

Solution: 1) $1 \div a = b \div x$, 2) $b \div a = 1 \div x$, 3) $c \div a = b \div x$.

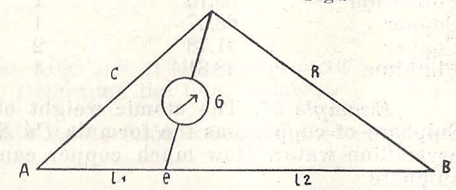
Example 31. A machine receive the effect N_1 and yields the output of N_2 then $\frac{N_2}{N_1} = \eta$.

a) *Motor:* $\eta = \frac{N_2\text{ PS}}{N_1\text{ kW}}; \frac{1\text{ PS}}{1\text{ kW}} = 0.736 =$ *Mot*, thus $N_1 : N_2 =$ *Mot* $: \eta$

b) *Generator:* $\eta = \frac{N_2\text{ kW}}{N_1\text{ PS}}; \frac{1\text{ kW}}{1\text{ PS}} = 1.36 =$ *Dyn*, alo $N_1 : N_2 =$ *Dyn* $: \eta$, see preceding example.

Example 32. A resistance *R* has to be detemined on a Wheatstone bridge by the help of a known resistance c = 20 Ω fig. 2. The German silver wire *AB* has the length *l* of 120 cm, the deviation of the bridge galvanometer dissappears, if AC= l= 43 cm, then BC=$l_2 = l - l_1$ = 77cm. Then we have the ratio of $l : l_2 = c : R$. In our case we have *R*=35,8 Ω.

Figur 2

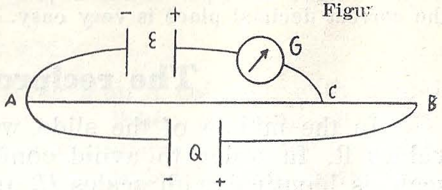


Example 33. Determine *R* in base of the values of c, l_1, l_2, in the following table

c	25	40	5	150	1200	Ω
l_1	24	50	83,5	72,5	94	cm
l_2	96	70	36,5	47,5	26	cm
R	100	56	2,19	98,3	332	Ω

Example 34. We have to compare the electromotive effect of different elements E_1, E_2, ... For this purpose we branch off one of them (E_1) from a circuit AQBA, in which the principal part is the straight wire *AB*, in which the element produces a current of the intensity of Q. The admission conductor *EC* can be shifted to *AB*. E_1, and *Q* are connected in opposition. If the galvanometer *G* indicates zero current *AC* = l_1. Replacing E_1 by E_2 we obtain instead of the distance l_1, the distance l_2. Then $l_1 \div E_1 = l_2 \div E_2$. E_1 is supposed to be a Weston normal pyle, the tension of which E_1=1.083 volts; this tension being known, we measure on *AB* l_1 = *56*. For the other pyles we determine l_2, l_3. Determine the voltage of same

Figur



Pyle.	Weston	Daniel	Grove	Meidinger	Bunsen	Immersion	Leclanché
l	56.0	54.6	95.4	56.7	93.1	119.2	72.9 cm

Solution: In the same sequence we have 1.083, 1.055, 1.845, 1.096, 1.800, 2.305, 1.410 volts as the electromotive effect of the pyles.

Example 35. Manganin alloy is composed of 12 % Manganese, 4 % Nickel and 84 % Copper. Determine the quantities of each of these elements contained in 275 g of Manganin alloy.

Solution: *x g Mn*, *y g Ni*, *z g Cu*. We have the proportion $100 \div 275 = 12 : x = 4 \div y = 84 \div z$. With a single setting of the slide we read: x=33, y=11, z = 231 g.

Example 36. We call electro-chemical equivalent weight the quantity of substance precipitated at an electrode by a current of *1A* in *1s*. By chemical valence weight we understand this to be the atomical weight divided by the valence. The law of FARADAY states that the electro-chemical equivalent weights are proportional to the atomic ones. Examine the following table:

Substance	Atomic weight	Valence	Chemical equiv. weight	Electro-chemical equ. weight
Hydrogen	1.008	1	1.008	0 01044
Aluminium	8.99	3	26.97	0.0932
Lead	103.6	2	207.2	1.074
Iron	27.92	2	55.84	0.2893
Iron	18.61	3	55.84	0.1929
Potassium	39.10	1	39.10	0.4052
Copper	63.57	1	63.57	0.6588
Copper	31.78	2	63.57	0.3294
Platinum	48.81	4	195.23	0.5057

Example 37. The atomic weight of Oxygen is 16, that of sulphur 32.06. Sulphate of copper has the formula $Cu\ SO_4 + 5H_2\ O$, the latter substance being crystalline water. How much copper can we precipitate from 340 g of copper sulphate.

Solution: x gr. The molecular weight of the sulphate of copper is 63.57 + 32.06 + 4×16 + 5 (2 016 + 16) = 249.71.

Then we get 249.71 ÷ 63.57 = 340 ÷ x; x = 86.6 g. With the same setting of the slide we can determine any quantity of sulphate of copper. We have only to set cursor line on the given number and read the result opposite

Thus we have							
	copper sulphate	100	1.8	4925	716	0.016	g
	copper	25.46	0.458	1254	182.3	0.004075	g

As the weight of copper is about 1/4 that of copper sulphate, determination of the correct decimal place is very easy.

The reciprocal scale R

In the middle of the slide, we have the scale of the reciprocal values R. In order to avoid confusion, it is engraved in red. The scale is identical with scales U_1 and U_2, only it runs from the right to the left. When setting the slide in the inverse position, we should state that scales U_1 and U_2 and R are identical, the cursor line in the different positions we may give it, always covering identical numbers on scales R and U_1. It will be quite clear that for calculating with scale R, slide must always be in its normal position.

$$1)\ x = \frac{1}{a}$$

a is given and the reciprocal value $x = \frac{1}{a}$ is sought. Solution: We set a on U_2 and we have x on R or inversely. The number of places is found easily by estimation. For instance we have opposite 5 of U_2 2 on R i. e. $\frac{1}{5} = 0.2$; $\frac{1}{50} = 0.02$; $\frac{1}{0.5} = 2$.

Example 38. Examine the following table

a	7	31	981	0,00014	0,068
$\frac{1}{a}$	0,1429	0,03226	0,001019	7143	14,71

We must take care, not to confuse scale U_2 with scale U_1 for determing the reciprocal value. This is best avoided by making the initial lines of both scales coincide exactly.

Example 39. The resistances $R_1 = 16.3\,\Omega$, $R_2 = 48.5\,\Omega$, $R_3 = 92\,\Omega$, $R_4 = 9.1\,\Omega$ are connected in parallel. Determine the total resistance R.

Solution: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = 0.0613 + 0.0206 + 0.0109 + 0.1099 = 0.2027$, $R = \frac{1}{0,2057} = 4.93\,\Omega$.

Example 40. Three condensors of 0,095 μF (1 Mikrofarad $= 10^{-6}$ Farad), 0.42 μF, 2.200 μF are connected in line. Determine the total capacity.

Solution: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = 10.531 + 2.381 + 0.455 = 13.365$; $C = \frac{1}{13.365} =$ 0.0748 μF

Example 41. Determine the length of a wire of the metals specified example 11 page 11 with a cross sectional area of 1 mm² in order to have a resistance of 1 Ω.

Solution: x metres we have $R = \frac{\varrho \cdot l}{q}$ thus $l = \varrho \cdot \varkappa$, $\varkappa = \frac{l}{\varrho}$. x is called specific resistance-conductance

Substance:	Aluminium	Lead	Iron (pure)	Copper	Manganin alloy	Nickel	Mercury	Silver
x	35.0	47.6	10.10	57.21	2.381	11.11	1.044	60.6

$$2)\ x = a \times b$$

Set cursor line to a on U_1 making b on R coincide with it and reading the result opposite *1* or *10* on U_2. When carrying out multiplications in this way, we never have to transpose the slide by unity. Calculate examples we read 1—4 recommended by this method.

$$3)\ x = a \times b \times c$$

Set b of R opposite a of U_1 then cursor line on c of U_2. Opposite this value, we have x on U_1. With the procedure as per page 9 we need to transpose the slide per unity, here only one setting. Calculate example 6 in this way.

Considering the characteristics of the reciprocal scale, we may write the above given examples as $a \times b = a : \left(\frac{1}{b}\right)$; $a \times b \times c = a \div \left(\frac{1}{b}\right) \times c$.

Just as $a \times b \times c \times d = a : \left(\frac{1}{b}\right) \times c : \left(\frac{1}{d}\right)$.

$$4)\ x = \frac{a}{b}$$

Setting: 1 or 10 of R, a on U_1, x is read on U_1 opposite b of R. This procedure is of special interest, if we have to calculate a series of fractions having the same numerator a but a differing denominator b_1, b_2, b_3.

Example 42. An accumulator having an electro-motive energy of 2 V and an inner resistance of $0.1\ \Omega$ has its terminal connected by a copper wire having a resistance of $R_{20} = 12\ \Omega$ at 20°.

Determine the alternation in the intensity of current-amperage if the temperature of the wire is increased successively from 20° to 30°.

Solution: According to page 12 the resistance increases by $R_{20} \times 0.00392 \times 2$, if the temperature increases by 2°, we obtein thus: $R_{22} = 12.094$, $R_{24} = 12.188$, $R_{26} = 12.282$, $R_{28} = 12.376$, $R_{30} = 12.470$. To these values we have to add the inner resistance of 0.1.

Thus the intensity of current at 20° will be $J_{20} = \frac{2}{12.1} = 0.1653$ A.

We have							
	t	20°	22°	24°	26°	28°	30°
	J	0.1653	0.1640	0.1627	0.1615	0.1603	0.1591 A

$$5)\ x = \frac{a \times b}{c}$$

We might also write: $x = a \div \left(\frac{1}{b}\right) \times \left(\frac{1}{c}\right)$.

Setting: a of U_1 opposite b of R, we read x of U_1 opposite c of R. This procedure is especially recommended if a and b are constant, whilst c assumes the values of c_1, c_2, c_3 successively.

Example 43. A coil of l cm length having the number of windings w and the winding surface q cm^2 has the self inductance $L = 4\pi \times 10^{-9} w^2 q/l$ *Henry*. assuming $n = 500$, $q = 3$ cm², l 10, 10.5, 11, 11.5, 12 cm respectively.

Determine L.

Solution: $4\pi = 12.57 \times 10^{-9} w^2 q = 12.57 \times 10^{-9} \times 2{,}5 \times 10^5 \times 3 = 7.5 \times 10^{-4}$,

$$L = \frac{12.57 \times 7.5 \times 10^{-4}}{l}$$

$L_1 = 0.0009425$, $L_2 = 0{,}0008975$, $L_3 = 0.000857$, $L_4 = 0.000820$, $L_5 = 0{,}000785$ Henry.

Inverse Proportions

If $a_1 \div a_2 \div a_3 \ldots = \frac{1}{b_1} \div \frac{1}{b_2} \div \frac{1}{b_3} \ldots$, we say that the numbers a are inversely proportional to numbers b.

Setting a_1 of U_1 coincidental to b_1 on R, a_2 on U_1 will also correspond to b_2 on R etc.

Example 44. Execute the preceding example in this way.

Solution: We have $L_1 : L_2 ; L_3 \ldots = \frac{1}{l_1} : \frac{1}{l_2} : \frac{1}{l_3} \ldots$ $L_1 = 0.0009425$ on U_1 setting 1 of R in coincidence we then proceed as explained above. The slide has the same position as in the preceding example.

Example 45. The capacitance of a glass plate covered on both sides with tin foil is proportional to the covered surface and is inversely proportional to the tickness d of the dielectric capacitance of the two layers of tin foil. $\left(\varrho = \frac{\varepsilon r\, F}{36\pi\, d} \times 10^{-5}\ \mu F,\right)$ εr dielectric constant. A glass plate ($\varepsilon r = 5$) of the diameter of d = 0.25 cm is covered on both sides with 8000 cm² of tin foil. Then its

capacitance $C = 0.1415$ microfarad. Determine this capacitance if the plate is 1, 1.25, 1.5, 1.75, 2.0, 2.25, 2.75, 3 mm thick respectively.

Solution: Designate the sought values as $C_1, C_2, C_3 \ldots$, $C_1 \div C_2 \div C_3 \ldots =$ and we obtain $\frac{1}{2{,}5} \div \frac{1}{1} \div \frac{1}{1.25} \div \frac{1}{1.5}$ etc.

On U_1 we read: $C_1 = 0.03538$, $C_2 = 0.02830$, $C_3 = 0.02358$, $C_4 = 0.02022$, $C_5 = 0.01769$, $C_6 = 0.01572$, $C_7 = 0.01286$, $C_8 = 0.01179\ \mu\ F$.

Square and Square roots

Moving the cursor line along to any number on U_1 or U_2 we have under the cursor line (coincidental to it) on O_1 or O_2 the square of this respective number. Thus we can state that $3^2 = 9$, $4^2 = 16$, $\pi^2 = 9.87$. It will be understood that for numbers beyond the range of 1—10, we must estimate the correct decimal point $0.0413^2 = 0.001706$, as $0.04^2 = 0.0016$; $4318^2 = 1.865 \times 10^7$, as $(4 \times 10^3)^2 = 16 \times 10^6 = 1.6 \times 10^7$.

In order to find $x = \sqrt{a}$; we set a on one of the upper scales, under the cursor line and in the respective position we have on one of the lower scales $x = \sqrt{a}$.

In this case, it is of no consequence whether or not, we utilize the right half or the left half of the scales. We set in the left one, if a is between 1 and 10, in the right one, if a is between 10 and 100 ($\sqrt{9} = 3$; $\sqrt{90} = 9.49$). If a is beyond these limits, we apportion the number towards the right and the left respectively, beginning at the decimal point in groups of 2 figures, each group corresponding to a place of the root viz. 12'34.56'78'90.

Example 46. Determine, what is the square root of the following numbere a) $\sqrt{8429}$, b) $\sqrt{8319722}$, c) $\sqrt{0.136}$, d) $\sqrt{0.01845}$, e) $\sqrt{0.000052}$?

Solution: As we have for a, two groups of two figures on the left hand side of the decimal point, the root will have two places $\sqrt{8429} = 91.8$, b) $x = \sqrt{8'31'97'22}$, $\sqrt{8.32} = 2.884$, $x = 2884$, c) $\sqrt{0.'13'60} = 0.3688$, d) $\sqrt{0.01845} = 0.1358$, e) $\sqrt{0.000052} = 0.00721$.

$$1.\ x = a^2 b$$

a) Setting 1 of U_2 opposite a on U_1 x is read opposite b of O_2. This procedure is recommended, if a is given and b is a variant.

b) Setting 1 of O_2 to coincide with b of O_1. x is read in coincidence with a of U_2 on O_1. We proceed in this way if b is the constant and a is the variable.

Example 47. A current "*I*" of 2.45 *A* flows through a wire, the resistances of which are a) 12.5 b) 133, c) 4.27 d) 0.89 Ω What is the output?

Solution: $N = J^2 R$ Watt. We choose procedure a and we get a) 75.0 b) 799, c) 25.6, d) 5.34 Watt as 1 Watt $= \frac{1}{736}$ PS $= \frac{1}{4186}$ kcal/s, this values can easily been converted.

Example 48. A wire having a resistance R, of 12.5 Ω shows a current of $I = 2.0$, 2.2, 2 4, 2.45, 2.6, 2.8. 3.0 A. Determine the amount of heat developed during one minute.

Solution: $Q = J^2 R \times 0.239 \times 60$ cal. In the present case $Q = 179\, I^2$ cal. By the method b we get 717, 868, 1032, 1076, 1212, 1406, 1613 cal. Compare the case of $I = 2.45$ A with the corresponding results of the former examples.

$$2.\; x = \frac{a^2}{b}$$

a) Setting cursor line to coincide with a on U_1, b on O_2 under cursor line, read x on O_1 opposite *1* of O_2.

b) Setting b of O_2 to coincide with 1 or 10 on O_1, cursor line opposite a of U_2, read x of O_1 under cursor line.

Example 49. An electric boiler is connected to a net of E Volts and heats a litres of water from 0° to 100° in t minutes.

Determine its resistance, the amperage of current and the output. Numerical values E = 220 Volts, t = 15 minutes $a = 1, 1.2, 1.5, 2$ l.

Solution: $Q = 100000\, a$ cal, $Q = J^2 R \times 0.239 \times 60\, t = \frac{14.34\, E^2 t}{R}$ cal. Comparison shows that $R = \frac{14.34\, E^2 t}{100000\, a} = \frac{E^2 t}{\cdot 6974\, a}\, \Omega$ is. $J = \frac{E}{R} A$, $N = EJ$ Watt.

In our case we have $R = \frac{E^2}{465\, a}\, \Omega$

a	1	1.2	1.5	2	l
R	104.1	86.7	69,4	52.0	Ω
J	2.11	2.54	3.17	4.23	A
N	465	558	697	930	W

Determine $\frac{220^2}{465}$ and divide the result on the upper scales by the different values of a or make use of the scales U_1 and R.

$$3.\; x = \sqrt{a\, b}$$

Multiply a by b with scales O_1 and O_2, setting cursor line on the result, reading under the line in this position x on U_1. $a\, b$ must be estimated in order to know whether we have to utilize the right or left half of scale O_1.

Example 50. From a lake, water is flowing out over the flat ridge of a weir. At each place the velocity is $v = \sqrt{2gh}$ m/s 1. if $g = 9.81$ m/s² and h the difference of level between the level of the lake and the corresponding place, determine v when $h = 0.75, 1.0, 1.25, 2.5, 3.5$ m respectively.

Solution: Set $a = 2g = 19.62$ on O_1 varying $b = h$ by moving the cursor along. We get 3.84, 4.43, 4.95, 7.0, 8.29 m/s. As calculations with $\sqrt{2g}$ occur frequently, we have had engraved on scale U_2 a gauge point for 4.429. Setting 1 or 100 of O_2 to coincide with h on O_1. We read v of U_1 in coincidence with $\sqrt{}$ on U_2.

$$4.\; x = \sqrt{\frac{a}{b}}$$

Example 51. The cross-sectional area of a wire is given as 5 mm². What is its diameter?

Solution: The radius being r mm, then $\pi r^2 = 5$, $r = \sqrt{\frac{5}{\pi}}$. π of O_2 to coincide with 5 of O_1, cursor line on 1 of O_2 not on 10, we read r on U_1 under the cursor line, $r = 1.262$ mm, $d = 2.524$ mm.

Example 52. Similar problem but the cross-sectional area is 50 mm².

Solution: Set π of O_2 to coincide with 5 of O_1 and then continue as in the above example, $r = 3.99$ mm, $d = 7.98$ mm.

Calculation of the Area of the Circle

With practical computation and measuring it is almost always easier to measure the diameter d of a circle than its radius, therefore for calculation the area of the circle we make use of the formula $A = \frac{\pi d^2}{4}$.

With our slide rule, the area can be computed in different ways. Example $d = 2.524$ mm, $A = 5$ mm, $d = 7.98$ mm, $A = 50$ mm² see above.

a) Set 10 of U_2 in line with d of U_1, opposite this value we have d^2 on O_1. This number without having been read is multiplied by $\frac{\pi}{4} = 0.7854$ for which number we have had a gauge point marked on scale O_2. Coincidental with it we have (on O_1) the value of $A = \frac{\pi d^2}{4}$.

b) On U_2 we have the gauge point $c = \sqrt{\frac{4}{\pi}} = 1.128$, this line is set to coincide with d on U_1 we then read the result on O_1 opposite 1 of O_2. We obtain $d^2 : \left(\sqrt{\frac{4}{\pi}}\right)^2 = d^2 : \frac{4}{\pi} = \frac{\pi d^2}{4}$.

c) On the glass cursor we have to the left and to the right of the centre line, further hair lines spaced at a distance of c. Setting middle cursor line on d of U_1, the result $\frac{\pi d^2}{4}$ we get under the left line on O_1. We can also set the right line on d of U_1 and read under the middle line on O_1. This is recommended, if we intend to utilize this result for further computations; for instance if we wish to determine the volume of a cylinder ($V = \frac{\pi d^2}{4} \times h$.)

Thes procedures should be used when the cursor has equally-spaced hair lines. When these distances are assymetrical, the centre line in combination with the left one, permits conversion of *PS* into *kW* or inversely (on O_1 or O_2).

If the area of the circle is given, we have only to reverse the procedure. According to a) we proceed as follows: $\frac{\pi}{4}$ on O_2 in line with A on O_1. Reading d on U_1 in coincidence with 10 on U_2. Setting of b and c is quite as easy as the present example. If the value of the area is smaller than 1 or greater than 100, we part it into groups of two figures similar to that shown for the square roots.

Example 53. If $d = 1$, 1.5, 2, 2.5, 3, 3.5, 4 mm respectively. What are the areas $\frac{\pi d^2}{4}$

Solution see example 10.

Example 54. What are the respective weights of a round rod of steel, if the length is constant 1 metre, the diameter 11, 12, 13, 14 and 15 mm and the specific gravity, γ of the steel is 7.85?

Solution: Calculating in cm, the weight will be $\frac{\pi d^2}{4} \times 100 \times 7.95$ g $= 0{,}785 \frac{\pi d^2}{4}$ kg. The results are 0.746, 0.888, 1.042, 1.208, 1.387 kg. Set 785 on O_1 in line with 1 of O_2 and move cursor line to the respective values of the different diameters on U_2. Results are read under the left cursor line on O_1.

Example 55. A thin silver wire weighing $G = 500$ g has the resistance R of 104.8 Ω. $\gamma = 10.5$ g/cm³, $\varrho = 0.0165$ Ω mm² m. Determine the length and the thicknes of the wire.

Solution: Calculating in *cm* and *g* we have (the cross-sectional area $= q cm^2$.) $ql\gamma = G$. 1) $ql = 47.6$; $\frac{0.01\, l \times \varrho}{100\, q} = R$. 2) $\frac{l}{q} = 6.35 \times 10^7$. $\frac{1)}{2)}$ gives $q^2 = 7.50 \times 10^{-7} = 75 \times 10^{-8}$, $q = 8.66 = 10^{-4}$ cm². From this we get $d = 3.32 \times 10^{-2}$ cm $= 0.332$ mm. The multiplication of 1 and 2 gives $l^2 = 3.025 \times 10^9 = 30.25 \times 10^8$; $l = 5.50 \times 10^4$ cm $= 550$ m.

Example 56. We wish to resolve the same problem but with the wire of a) iron ($\gamma = 7.88$, $\varrho = 0{,}099$), b) copper ($\gamma = 8.93$, $\varrho = 0{,}0175$), c) nickel ($\gamma = 8.8$, $\varrho = 0{,}09$), d) German silver ($\gamma = 8.5$, $\varrho = 0.4$). The resistance R and the weight G have the same values as in the example 55.

Solution: Representing the procedure by formula. We have:

$$q = \sqrt{\frac{G\varrho}{\gamma R}} \text{ mm}^2, \quad l = \sqrt{\frac{RG}{\gamma \varrho}} \text{ m.} \qquad \sqrt{\frac{G}{R}} = 2.184, \quad \sqrt{GR} = 229, \quad \text{thus: } l = \frac{229}{\sqrt{\gamma\, \varrho}},$$

$q = 2.184 \sqrt{\frac{\varrho}{\gamma}}$. a) $l = 259.2$ m, $q = 0.2448$ mm², $d = 0.558$ mm. b) $l = 579$ m, $q = 0.0967$ mm², $d = 0.3508$ mm. c) $l = 257.3$ m, $q = 0.2209$ mm², $d = 0.530$ mm. d) $l = 124.2$ m, $q = 0.474$ mm², $d = 0.777$ mm.

Scales of Cubes K

The scale engraved on the vertical edge of the stock has three sections and runs from 1—1000. This scale may be derived from scale U_1 by the reduction in the ratio of 1 : 3 and joining in a line the sections thus obtained. Lateral index line as a continuation of the centre cursor line allows us to bring into line any value on scale K with the values on the other scales. Scale K is for determining third powers and third roots.

1) $x = a^3$

Set cursor line on a of U_1, and read x below index line on scale K. Examine procedure first with easy examples such as $2^3 = 8$, $3^3 = 27$, $5^3 = 125$. If a is not between 1 and 10, we must displace the decimal point by three times as many places as with a for reading x, for instance $0.2^3 = 0.008$, $20^3 = 8000$, $0.05^3 = 0.000125$.

Example 57. Determine $x = 1.913^3$, 4.12^3 8.88^3, 0.1913^3, 41.2^3, 888^3.

Solution: $x = 7$, 70, 700, 0.007, 70000, 7×10^8

As the distances of the lines are narrower on this scale, we cannot get the same precision of reading as with the other scales. If we wish to determine $x = a^3$ more exactly, we have the following possibilities

a) Setting 1 of U_2 to coincide with a of U_1, cursor line to coincide with a on O_2 cursor line on x of O_1 x ($a^3 = a^2 \times a$).

b) a on scale R is brought into line with a on U_1 and the cursor line set on a of U_2. x is read under cursor line on U_1. In the first case, we can continue calculation on O_1, in the second one on U_1 with $x = a^3$ if this is required.

2) $x = n\, a^3$

Setting of 1 or 10 of U_2 opposite n of k with cursor line on a U_2. x is read on K under cursor line.

Example 58. Determine the contents of a sphere of diameter *d*. *a)* = 1.5, *b)* 13.6, *c)* 233 cm.

Solution: $V = \frac{\pi}{6} d^3 = 0.5236\, d^3$. We have a) $V = 1.77$ cm³, b) $V = 1320$ cm³ c) 6.62×10^6 cm³ $= 6.62$ m³.

3) $x = \sqrt[3]{a}$

As shown in example 57, the sequence of figures in the results of $\sqrt[3]{7}$ $\sqrt[3]{70}$ $\sqrt[3]{700}$ is different. We have to divide the respective numbers into groups of three figures in order to ascertain in which section of scale K we must seek a. The result is read on scale U_1.

Example 59. If the output for a shaft is given as *N PS* (the number of revolutions *n* per minute), the diameter can be calculated according to the formula $14.42 \sqrt[3]{\frac{N}{n}}$ cm. Determine the value of $\frac{N}{n}$ for 0.01, 0.02, 0.042, 0.07, 0.144, 0.14, 0.25.

Solution: Set 14.42 of U_2 in alignment with 1 of U_1 and then index line $N:n$ on K. The result is read under the cursor line on U_2. We obtain $d = 3.11$, 3.92, 5.01, 5.94, 6.99, 7.49, 9.08. In practice we should naturally round off the results.

The Trigonometrical scales

On the back of the slide we have the scales of *S*, *S & T*, and *T*. Reverse the slide, setting it thus, so that initial lines of these scales coincide with 1 of U_1.

1. The Sine

a be an angle between 5° 45, and 90°. Then we find sine a on S by the cursor line and finding the corresponding value of the sine on scale U_1 under cursor line. As the values of the sines for the above mentioned angles are between 0.1 and 1, the results must begin by O, for instance sine $30° = 0.5$.

If a is between 0°34′20″ and 5°45′, we proceed in the same way, setting on scale *S & T*. Results here begin with 0.0 for instance sine $1°0' = 0.01745$. If the angle is still smaller, we have $sin\ a' \approx \frac{a'}{3438}$, for instance

$$sin\ 1°0' = sin\ 60' = \frac{60}{3438} = 0.01745,\ sin\ 35'30'' = \frac{35.5}{3438} = 0.01033.$$

We can also leave the slide in its normal position and set a in the right notch on the back, reading sine a in line with 10 of U_1 on U_2.

2. The Function of Tangent

If a is between 5°43′ and 45° we determine a on T. The result is read under the cursor line on U_1. It begins by O, for instance $tg\ 40°20' = 0.849$.

Up to $a = 5°43'$, $tg\ a \approx sin\ a$, and we make use of scale *S & T*, for smaller angles $tg\ a \approx sin\ a \approx \frac{a'}{3438}$.

With the normal position of the slide, we set a on the left notch of the back of the stock, reading $tg\ a$ in line with 1 of U_1. If a is between 45° and 90° we have $tg\ a = \frac{1}{tg\ (90° - a)}$, $tg\ (90° - a)$ can be calculated according to the explanations given, $tg\ 52°15' = \frac{1}{tg\ 37°45'} = \frac{1}{0.774} = 1.292$. Leaving the cursor line on 0.744, we turn the slide and then we read the result of the last division on scale R. We can also set $90° - a = 37°45'$ coincidental to 10 of U_1 and read $tg\ a = 1.292$ under the initial line of the tangent scale:

With the normal position of the slide, we set $90° - a$ on the left notch reading the result on R coincidental to 1 of U_1.

3. Cosine and cotangent

If we have to determine $cos\ a$ or $ctg\ a$, we avail ourselves of the formulae $cos\ a = sin\ (90° - a)$, $ctg\ a = tg\ (90° - a) = \frac{1}{tg\ a}$.

Example 60. Determine the trigonometrical functions for $a_1 = 13°14'$, $a_2 = 57°0'$, $a_3 = 4°11'$, $a_4 = 0°0'30''$?

Solution:

a	13°14′	57°	4°11′	30″ = 1/2′
sin a	0.229	0.839	0.0730	0.0001455
cos a	0.973	0.545	0.997	1.000
tg a	0.235	1.540	0.0730	0.0001455
ctg a	4.25	0.649	13.7	6875

Example 61. An *AC* machine has a pressure of U *Volts*, an amperage of *I Amperes*, with the power of *N watts*. Determine the angle of phases.

Solution: $N = UJ \cos \varphi$, $\cos \varphi = \frac{N}{UJ}$.

Examine tho following examples:

U	220	110	500	350	Volt
J	80	60	9	150	Ampére
N	14.50	5.15	4.00	39.0	Kilowatt
cos φ	0.824	0.7805	0.889	0.743	
φ	34°30′	38°40′	27°15′	42°	

Example 62. The reactive power N_b is equal *to U I sine* φ. Calculate same for the in the preceding example.

Solution: 9.97, 4.13, 2.060, 35.13 kW. Proof: $N^2 + N_b{}^2 = (UJ)^2$.

Example 63. Draw the sine line so important for AC current.

Solution: Draw a straight line $2\pi = 6.28$ cm long, and divide it into 36 equal distances. Then the initial point corresponds to the angle of 0°, the first division mark to 10°, the second to 20° and so on. Draw a line normal to each division point corresponding to the sine of the respective angle. We have to consider the formulae $sin\ (180° - a) = sin\ a$, $sin\ (180° + a) = -\ sin\ a$, $sin\ (360° - a) = -\ sin\ a$. Positive values of the sines are drawn upwards negative ones downwards. Finally the end points of the lines are connected by a curve line,

Example 64. The reduction factor of a tangential compass is $C = 5.82$. By a current of the intensity of *I Amperes* the needle is deviated by $\alpha = 3°15'$. What is the intensity?

Solution: $J = C \times tg\ a = 5.82 \times 0.0568 = 0.330\ A$.

Example 65. Using the same compass, the amperage of current is increased and the needle shows successive deviations of 6°, 6°30′, 7°10′, 7°55′, 8°0′. What is the intensity of current in each case?

Solution: As we have to multiply by the constant factor of 5.82, we fix this value on U_1, using the cursor line, then turn the slide so that the trigonometrical scales are uppermost on the stock scales. Then we set the initial line of the trigonomotrical scales under cursor line. Moving the cursor line along to the required angle, on T, the value of I is read in alignment with T on scale U_1 (i. e. under cursor) $J = 0.612$; 0.663; 0.732; 0.809; 0.818 *A*.

Example 66. A current of 2.50 *A* flows through a tangential compass the deviation of which is 17°5′. Then follow other currents of which result deviations of 8°35′, 10°0′, 15°0′, 19°20′, 22°5′. Determine the intensity of the respective currents.

Solution: $C = \frac{J}{tg\ a} = \frac{J_1}{tg\ a_1}$ . . . We again set the trigonometrical scales adjacent to the stock scales ("reversing the slide") setting 17°5′, on the T scale, in line with 2.5 of U_1. Finally cursor line is set on the requisite angle and under the line the intensities of current namely 1.228, 1.434, 2.18, 2.854, 3.30 A are read.

The Scale of Power P

The scale of powers is traced on the vertical edge of the stock. It is superimposed to the cube scale. It extends from 1.08 to 100000 and serves for determining powers and roots with any exponent, as well as for determining the mantissae of logarithms with any base. This power scale corresponds with scales O_1 and O_2.

1. Setting the centre cursor line to 10 of O_1, it is coincidental to $e = 2.718$ of P; if we set it on 20 of O_1, we have on P, $e^2 = 73.9$

with 30 we have $e^3 = 20{\cdot}1$ etc. With this procedure, numbers on the right half of O_1 scale must be read as 1 , 2.0 . . . 10.— instead of 10, 20, ... 100, on the left side as 0.1, 0.2, ... 1.0. If the exponet is less than 0.1 the scales do not extend to values below this limit, we calculate by series development $e^x = 1 + \frac{x}{1} + \frac{x^2}{1\times2} + \frac{x^3}{1\times2\times3} \cdots$ which gives the result rapidly.

Example 67. If a rope is stretched in contact with part of the circumference of a cylinder, there is friction between both. For calculating this friction, we make use of the expression $e^{\mu\alpha}$ — μ being the coefficient of friction and α the arc of contact expressed in the measurement of arc $\left(\alpha = \frac{\pi\,\alpha^\circ}{180^\circ}\right)$

N. B, Do not confuse μ for mechanics with μ for electrics. In the latter case it is the amplication factor $= \left(\frac{\text{Anode volts change}}{\text{Grid volts change}}\right)$

We take from a technical handbook for $\mu = 0.1$ the following table

$\frac{\alpha}{2\pi}\left(=\frac{\alpha^\circ}{360^\circ}\right)$	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	3.5	4.0
$e^{\mu\alpha}$	1.13	1.29	1.46	1.65	1.87	2.57	3.51	4.81	6.59	9.02	12.35

Examine same with the slide rule.

Solution: If $\frac{\alpha}{2\pi} = 0.2$, $\alpha = 0.4\,\pi$, $\mu\alpha = 0.1257$. We get on the left side of scale O_1 $e^{\mu\alpha} = 1.134$. The following results are 1.286, 1.458, 1.653, 1.874, 2.57, 3.51, 4.8, 6.6, 9.0, 12.3. The commencing results are more precise than the table, for as we go towards the right, precision decrease as a result of the distances between the division lines becoming narrower. Small transformations such as $(0.1\times2\pi\times0.2,\ 0.1\times2\pi\times0.4)$ and so on can be avoided. Setting 10 of O_2 to coincide with 2π of O_1 cursor line is set subsequently to 2, 4, 6, ... of O_2 and the result read on P under index line.

Example 68. Determine the natural logarithms of 3, 4, 5, etc. further of 3.75, 13.8, 33.4, 125.2, 1.25, 2, 0.75, 0.00123.

Solution: If $x = ln\,a$, $e^x = a$. Set cursor line to coincide with a on P, and read on O_1 under cursor line the value of $ln\,a$. We get $ln\ 4 = 1.386$, $ln\ 5 = 1.610$, $ln\ 6 = 1.792$, $ln\ 3.75 = 1.322$, $ln\ 13.8 = 2.625$, $ln\ 33.4 = 3.51$, $ln\ 125.2 = 4.83$, $ln\ 1.25 = 0.223$, $ln\ 2 = 0.693$, $ln\ 0.75 = \left(\frac{1}{1.333}\right) = 0 - ln\ 1.333 = -0{,}288$, $ln\ 0.0123 = ln\left(\frac{1}{81.3}\right) = -4.40$.

Natural logarithms are frequently made usn of when calculating the selfinduction and the capacity for single conductors and triangular tension.

2) If we have set O_2 exactly coincidental to O_1, it does not matter which of the two scales we read. Let us now set 10 of O_2 to any number of a on P. Then shifting cursor so that it is coincidental with $10\,n$ on O_2 we read under cursor index on P, a^n. If we choose $a = 2$ we get by setting the cursor line on 20, 30, 40, of O_2 on p the powers $2^2 = 4$, $2^3 = 8$, $2^4 = 16$ etc. which can easily be examined mentally. For n we can also assume a fraction, for instance the value

of 1.41 so important in thermodynamics, we get $2^{1.41} = 2.66$. For 3 $3^{0,5}\left(=\sqrt{3}\right) = 1.73$; $3^{0,333}\left(=\sqrt[3]{3}\right) = 1.442$; $\sqrt[5]{2000} = 2000^{0.2} = 4.57$

$x = \sqrt[n]{a}$ can also be determined in the following way:—

Setting 10 n of O_2 in line with a on P, cursor line on 10 of O_2 and reading x on P under cursor line. Besides powers and roots to any positive base and to any positive exponent, scale P also gives logarithms to any base. The most in use are the decadal ones, base 10. If $x = lg\ a$, $10^x = a$.

Setting 10 of O_2 coincidental to 10 of P, cursor line on a on P, x is read under cursor line on O_2.

Example 69. Determine the decadal logarithms of the values given in the example 76.

Solution: $lg\ 3 = 0.477$; $lg\ 4 = 0.602$; $lg\ 5 = 0.699$; $lg\ 6 = 0.778$; $lg\ 3.75 = 0.574$; $lg\ 13.8 = 1.14$. Calculating $lg\ 13.8 = lg\ 10 \times lg\ 1.38$ we find the more exact value of 1.140 the zero being certain. $lg\ 33.4 = 1 + lg\ 3.34 = 1.524$; $lg\ 125.2 = 2.0975$; $lg\ 1.25 = 0.097$; $lg\ 2 = 0.301$; $lg\ 0.75 = 0.875 - 1$; $lg\ 0.0123 = 0.0899 - 2$. Proof: $lg\ a = 0.4343 \times ln\ a$.

Example 70. In example 7 on page 9 we have sought q^n, q being 1.06, $n = 1, 2, 3 \ldots 10$. Solve the problems with the scale P. As P does not contain the value 1.06, we make use of the formula $q^n = (q^2)^{\frac{n}{2}}$. In this case $q^2 = q_1 = 1.1236$. We have to form q_1^1, $q_1^{\frac{2}{3}}$, $q_1^2 \ldots q_1^5$. Of course the results correspond with those obtained in that example.

Example 71. A coil has the resistance of $R = 200\,\Omega$, its self-inductance is $L = 0.2$ Henry. At the extremity there is a tension of $U = 20$ Volt. The current is not immediately $J = \frac{U}{R} = 0{,}1\ A$, because the self-inductance after t seconds $J' = \frac{U}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$. Similar the current does not disappear immediately after disconnecting because after t seconds it still has the intensity of $J_t = \frac{U}{R}\,e^{-\frac{Rt}{L}}$ Determine in our case the intensity t seconds after connecting and disconnecting, if $t = 0.001, 0.002, \ldots 0.005$ s.

Solution: $J = 0.1\ (1 - e^{-1000\,t})$, $J' = 0.1\ e^{-1000\,t}$ also $J = 0.1 - J'$.

t	0.001	0.002	0.003	0.004	0.005	
$e^{1000\,t}$	2.718	7.39	20.1	55	148	
$e^{-1000\,t}$	0.368	0.135	0.050	0.0183	0.00674	
J'	0.0368	0.0135	0.0050	0.0018	0.00067	Ampere
J	0.0632	0.0865	0.0950	0.0982	0.0993	Ampere

The third line results are derived from the second by making use of scale R.

Example 72. With a ballistic galvanometer of which the ratio of reduction is x, $(ln\ x = \lambda)$ we have between the deviation not reduced and that reduced the ratio $\frac{\beta}{\alpha} = x^{1/\pi\ arctg\,(\pi/\lambda)} = n$. Confirm the following table

x	1.5	2	2.5	3	3.5	4
n	1.205	1.350	1.458	1.542	1.608	1.667

Solution: In the first case $\varkappa = 1.5$, $\lambda = 0\,406$, $\frac{\pi}{\lambda} = 7.75 \left(= \frac{1}{0.1291} \right)$; $arctg \left(\frac{\pi}{\lambda} \right) = 90^0 - 7^0 21' = 82^0 39'$. In the measurement of arc $\frac{82.65}{57.3} = 1.443$. Then $1/\pi \; arctg \; (\pi/\lambda) = \frac{1.443}{3.142} = 0.459$, $n = 1.5^{0.459} = 1.205$. The other cases are calculated correspondingly.

If the reader is convinced that our slide rules can be made use of with great advantage in the different spheres of electrotechnics in that they free the user from the burden of tedious numeral calculations enabling him to deal more fully with the essential problems, then we think we have reached our aim.

Other NESTLER Slide Rules:

No.	Designation	Used by:	Lengt of scales cm	Inches
11 D	"Darmstadt"	Engineers, Mathematicians	12,5	5
11 B	"Steel concrete" (Tension 1400 kg/cm² n=15)	Architects	12,5	5
11 E	"Electro"	Electricians	12,5	5
11 H	"Timber trade"	Timber merchants etc.	12,5	5
11 K	"Commercial"	Merchants, Bankers etc.	12,5	5
11 R	"Rietz"	Engineers and all professions	12,5	5
11 M	"Mannheim" with S- and T-scale	Engineers and all professions	12,5	5
11 O	"Mannheim" without S- and T-scale	Engineers and all professions	12,5	5
7/52	"Commercial" made of white material ANAGIT	Students	25	10
9	**Rietz** with reciprocal scale	Students	25	10
14/52	"Engineer" of white ANAGIT	Students	25	10
21*	**Darmstadt**	Engineers,	25	10
21 a	"	Mathematicians, Scientists	50	20
22	**Rietz** with reciprocal scale	Engineers and all other professions	15	6
23/3	" without " "		25	10
23R/3*	" with " "		25	10
23aR/3	" " " "		36	14
24 R	" " " "		50	20
24R/100	" " " "		100	40
23 R/52	" " " "		25	10
26	**Engineer's** (with scale for weights for all metals of any section)	Mechanical and Industrial Engineers, Foremen of mechanical workshops, Time Study Experts etc.	25	10
27	**"»Precision«"** (scales in double	Engineers and all other professions	25	10
27 a	" length intercepted)		50	20
28*	**"Universal"** (for topographical	Surveyors	25	10
28 a*	" and tachimetrical calculations)		50	20
				10
29	Log-Log Trig Type	Scientists, Engineer and all other professions	25	10
33	**"Chemist"**	Chemists	25	10
36	**"Electro"**	Electricians	25	10
37	"		25	10
37 a	"	Electricians	50	20
40	**"Commercial"**	Merchants, Bankers	25	10
40 a	"	Economists	50	20
40 n	**"Commercial"** with power scales for compound interests		25	10
43	**"Hoffmann" Steel-concrete** (for tensions 1200 and 1400 or 1400 and 1800 kg/cm² n = 15	Architects, Architectural engineers	25	10
43 a	**"Dr. Schaefer" Steel-concrete** (for tensions 1200 and 1400, or 1400 and 1800, or 2000 and 2400 kg/cm² n = 15	Architects, Architectural engineers	25	10

*) may be furnished with scales for the angular functions divided in 360⁰ or 400⁰

Velvet lined walnut cases for slide rules of 25 cm.................. | of 50 cm..................

Demonstration slide rules for schools No. 23 D "Rietz".................. No. 21 D "DARMSTADT"