# CALCULATING CIRCLE

— *Calculigraphe H. C.* —

## BOUCHER'S SYSTEM

With Improvements

H C

Trade

Mark

MOVEABLE DIAL

By means of the "key" of the instrument one is able to bring under the needle or under the index any desired division of the moveable dial, and also by means of the "key" the needle can be turned on either dial to any division whatever.

By the combination of the different positions which may be occupied by the needles and the moveable dial, proceed the rules to be followed in order to accomplish the different operations possible with this instrument.

## Scales of the Moveable Dial.

The scales of the moveable dial are :

1. The scale of the ordinary numbers marked on the third interior circle.
2. The scale of the squares marked on the two first interior circles.
3. The scale of the sines of angles marked on the exterior circle.

## Scales of the Fixed Dial.

The scales of the fixed dial are :

1. The scale of the cubes marked on the three interior circles.
2. The scale of the decimals of the logarithms marked on the exterior circles.

## Representation of the Logarithms on the Dials of the Instrument.

The logarithms are represented on the dials by arcs, all of which have the same point of origin and are as portions of the entire circle proportional to the logarithms.

Considering the scale of the ordinary numbers on the moveable scale :—

The log. of 1 being 0 is represented by the same point of origin of the angles marked 1.

The log. of 2 being 0,30103 is represented by the arc 1-2 reckoning 30103 parts of the circle divided into 100,000 equal parts.

The logg. of 3 being 0,47712 is represented by the arc 1-3 reckoning 47712 of these parts.

In the same way the arcs 1-4, 1-5... 1-9 represent the logarithms of the numbers 4-5... 9.

The log. of 10 being 1 is represented by an entire circle.

The log. of 12 being 1,07918 is represented by the arc which has an entire circle in addition to the part 1-12 containing 7918 of the 100,000 parts of the circle.

The log. of 120 being 2,07918 is represented by the arc which has for its measure two complete circles in addition to the part 1–12.

The log. 1,2 being 0,07918 is represented by the arc 1-12.

The log. of 0,12 being 1,07918 is represented by an arc which has a dimension of the arc 1-12 less an entire circle.

Generally, all logarithms of numbers greater or smaller than unity are represented by a number of complete circles, more or less, equal to the characteristic positive or negative with the addition of part of a circle proportional to the decimal part.

If to the arc corresponding to the log. of 2 one adds the arc corresponding to the log. of 3 one forms the arc corresponding to the log. of $6=2\times3$.

In order to add these two arcs to the extremity, the one of the other, it is necessary, (the figure 1 of the dial being at the index), to turn the dial in the direction 1, 9, 8... until the figure 2 is directly under the index, then placing the needle on 1, it is necessary to make use of it as a mark, in order to pass under this point the arc of 3, turning the d al always in the same direction. In this movement an equal arc will pass under the index, which will then indicate the sum of two arcs.

Reciprocally, if one passes under the index by turning the dial in the direction 1, 9, 8... the arc 6, and if one repasses under this point (by turning the dial in the contrary direction) an arc equal to the arc 3, the index will indicate the number 2=6 : 3 of which the arc is the difference of two others. Moreover, in order to repass under the index an arc equal to the arc 3, it is sufficient to place the needle as a marker on the 3, by turning the dial in the direction 1, 2, 3... to place the 1 under the needle. In this movement the arc of 3 has passed under the needle in the same time as an equal arc has repassed under the index.

It is evident, therefore, up to the present that by adding the arcs one to the other, or by subtracting the one for the other, one multiplies or divides between them the numbers that they represent.

## Division and Reading of the Moveable Dial.

### 1. *Scale of ordinary numbers.*

The 3rd interior circle on which is marked this scale is divided into nine great integral parts diminishing gradually, and each of these nine principal parts is divided into 10 parts also unequal and following the same law of decrease.

The 9 principal divisions indicate the numbers 1,2,3....9 as well as the multiples and decimal sub-multiples of these numbers, as : 10,20,30....90; 100,200,300....900, etc., and 0.1,0.2,0.3...0.9; 0.01,0.02,0.03....0.09, etc.

The 9 secondary spaces placed between 2 of the principal divisions indicate unities of an order immediately inferior to that of the unities indicated by these principal divisions.

The secondary divisions are numbered by twos between the principal spaces 1 and 2, as 12, 14, 16 and 18; and by fives between 2 and 5, as 25, 35 and 45, the fifth of these divisions is indicated only by a longer mark of division between 6 and 7, 7 and 8, 8 and 9, 9 and 1.

The 10 secondary divisions between 1 and 2 have been divided each into 5 equally decreasing parts, each representing 2 units of an order immediately inferior to that of the secondary divisions which they compose.

The secondary divisions between 2 and 6 have only been able to be divided into 2 parts each and unequal following the same law of decrease and both representing 5 units of an order immediately inferior to that of the secondary divisions of which they are part.

The secondary divisions between 6 and 1 have not been divided on account of the smallness of the space between the divisions.

If one turns the "key" of the instrument at the same time pressing the button we can point the needle wherever we please, we indicate : first the number 1 at the commencement of the divisions, number 2 indicated by the second principal divisionary mark, 3,4,5,6,7,8,9 indicated by the other principal marks, and finally 10 indicated as 1 by the 1st principal division.

One can also indicate by the needle all the numbers comprised between 10 and 100 by turning it successively to all the secondary divisions, the first secondary division after 1 indicating 11, the second indicating 12, the third secondary division after the principal division 4 indicating 43 and the fourth 44; the last but one of these division marks represents 98 and the last 99.

Continuing to point the needle one passes a second time on the principal division mark 1, and this time one reads there 100. Pointing the needle to the 1st tertiary division mark following, one reads 102 and on the second one reads 104. If we arrest the needle nearly half way between the first tertiary division one reads 101, nearly half the distance between the 2nd and the 3rd one reads 103, and in the same manner one rea[illegible] 107, 109... by positions not indicated by the division marks, but nevertheless with exactitude.

Again turning the needle it will when pointing to the 1st secondary division mark 11 indicate 110, and passing to the 1st tertiary division mark following it will indicate 112. Further if one stops the needle a little before the principal mark 2 after having passed the preceding tertiary division mark and almost equal distance from these two marks, though nearer, however, to the 1st than to the 2nd in order to continue observing the law of decrease in the divisions, one reads 199.

The needle next passed on the principal mark 2 one reads there this time 200, the tertiary mark following will indicate 205 and so on successively 210,215,220,225... until the number 595 represented by the tertiary division mark preceding the principal division mark 6.

The numbers comprised between these latter as 201,202..., 598,599 are not indicated by division marks, but after practice with the instrument, one will be able to point the needle between the space of a tertiary division in such a manner that it will indicate all these numbers.

It is only by an estimate, that would become day by day finer than one can indicate with the needle between the principal marks 6 and 1 all the numbers comprised between 600 and 1000 and that by mentally dividing into 10 parts each of the secondary divisions comprised between these marks.

Practice with the instrument will also lead to the indication of numbers of four figures between the principal marks 1 and 2 and with sufficient approximation.

The numbers which cannot be indicated on the instrument in an absolutely exact manner can be indicated approximately by considering only the three or four first figures on the l ft. Thus in the number 803425 one indicates 803 only, and for 1035327 one indicates 1035.

## 2nd *Scale of Squares.*

The scale of squares is marked on the two first interior circles, and is divided exactly like the scale of ordinary numbers, with this difference that its development being double that of the ordinary scale, each arc of number is composed of a number of parts of circles twice as great in the scale of squares as in the scale of ordinary numbers.

As a result, when turning the needle and from the commencement of the divisions, one traces—to indicate on the scale of squares a certain number—a course double that which one traced on the scale of ordinary numbers to indicate the same number.

When, for example, the needle has traced the arc 1-3 on the scale of squares, it will have traced twice the arc 1-3 on the scale of numbers and in consequence will indicate $3 \times 3 = 3^2 = 9$.

Then again the needle when stopped at a number on the scale of squares will indicate the square of this number on the scale of numbers.

Reciprocally the needle stopped at a number on the scale of numbers will indicate the square root of that number on the scale of squares.

But, here, one will notice that the needle meets the scale of squares in two points—to know on which of the two circles one ought to read the square root required, one divides the proposed number into periods of two numbers by starting from the figure of unity or from the comma and moving from right to left for those numbers greater than 1 and from left to right for those less than 1. When the first period of significant numbers on the left is one single number, one takes the square root on the 1st interior circle, and when this period is two numbers, one takes the root on the 2nd circle.

Examples: The numbers 400, 4, 0.04, 0,0004 have their square roots on the 1st interior circle and the numbers 4000, 40, 0.40

0.0040 have their square roots on the 2nd circle.

### 3rd *Scale of Sines.*

This scale marked on the exterior circle gives the angles by ten minutes spaces from 6° to 20°, by 20 minutes spaces from 20° to 30°, by 30 minutes, spaces from 30° to 35° by degree spaces from 45° to 70° and by 5 degree spaces from 70° to 90°.—The cosines of an angle A being equal to the sines of its complement 90°—A one easily indicates on this scale the cosines of angles by mentally putting in the place of the figured angles 6,7,8... 40,50... the complements of these 84,83,82 .. 50,40... and by reading the intermediary divisions in the direction opposite to that in which one reads them for the sines.

## Division and Reading of the Fixed Dial.

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### 1st *Scale of Cubes.*

The scale of the cubes is marked on the three interior circles. If only its greater expansion had permitted the tertiary divisions to be more numerous than on the scale of the ordinary numbers, it should be divided exactly as this latter with the difference that its expansion being the triple of its own, each arc of a number is composed of a number of parts of circles three times greater in the scale of cubes than in that of numbers.

It therefore follows that starting from the point of departure of the divisions, one turns the needle, to indicate on the scale of cubes route triple any number wh[illegible] that necessary to indicate the same number on the scale of ordinary numbers.

When, for example, the needle has traced the arc 1-3 on the scale of cubes, it has traced three times the arc 1-3 on the scale of numbers where it will indicate, the 1 of the dial being at the index $3 \times 3 \times 3 = 3^3 = 27$.

Then the needle of the fixed dial being arrested at a number on the scale of cubes, the needle of the moveable dial will indicate the cube of this number, on the scale of numbers, the 1 of the dial being at the index.

Reciprocally the needle of the moveable dial being arrested on a number of the scale of numbers, the 1 of the dial being at the index, the needle of the fixed dial will indicate the cubic root of this number on the scale of cubes.

But [illegible] one will notice that th[illegible] the scale of cubes in three points. To know on which of the three circles one ought to read the required cubic root one divides the proposed number into series of three figures by starting from one figure of unity, or from the point and moving from right to left for numbers greater than one, and from left to right for those less than one. When the 1st series of significant figures on the left is a number, one takes the root on the 1st interior circle, when there are two numbers the root is found on the 2nd circle; and finally, when the series is one of three figures, the root is found on the 3rd circle.

Examples: The numbers 4.000, 4, 0.004 and 0,000.004 have their cubic roots on the 1st interior circle; the numbers 40.000, 40, 0,040 and 0,000.040 have their roots on the 2nd circle; the numbers 400,000, 400, 0,400, and 0,000.400 have their roots on the 3rd circle.

*2nd Scales of Decimals, of Logarithms.*

The exterior circle is divided into ten principal parts equal and numbered from 1 to 10. Each of these parts is itself divided into ten other equal parts, and finally each of these secondary divisions is divided into two new equal divisions. It follows, that whatever may be the value attributed to the principal divisions, the secondary divisions have a value ten time less and each of the tertiary divisions has [illegible] of half or five tenths of a secondary unit.

That being granted, one sees that it is easy to indicate on this scale, by means of the needle, all numbers by fives between 1 and 1,000 and, by supposing mentally that the space between two divisionary marks is divided into five equal parts, one arrives very quickly to place the needle in these spaces in such a position as to indicate every number from 1 to 1,000.

The letters $n$, $n^2$, $n^3$ placed at the side of the 1 of each of the scales of numbers, squares and cubes are distinguishing marks.

## Resolution of Problems.

Whatever may be the problem to be solved and to whatever science it belongs it always reduces itself to the solving of a numerical formula indicating one or several of the operations of arithmetic.

These operations are performed on the scale of numbers, where one can then read the results even when one has introduced into the calculations values taken on the other scales of squares, cubes, or sines.

## Operations of Arithmetic.

### *Multiplication.*

To multiply one number by another, as $a \times v$; one brings $a$ under the index, then point the needle on 1 ond bring $v$ under the needle, the index will indicate the product. In the case of $v$ variable in the formula $a \times v = x$, to each value of $v$ led under the needle corresponds a different value of $x$ under the index.

### *Division.*

To divide the number by another, as $a : b = x$ : one brings under the index the needle on $b$ and under the needle, the index will indicate the quotient $x$. Or also the 1 of the dial being at the index, if we point the needle on $b$ and place $a$ under the needle, the index will indicate $x$. In operating in this second manner, in the case of $a$ being variable as in the formula $a : b = x$, to each value of $a$ led under the needle corresponds a different value of $x$ under the index.

## Proportion.

To find the fourth term of a proportion of which one knows the three first, one leads the 2nd term under the index, then one points the needle to the first and finally brings the 3rd under the needle. Then the index will indicate the fourth term. If in the proportion $a : b :: v : x$, $v$ is variable, to each value of $v$ brought under the needle corresponds a different value of $x$ under the index. Generally the index and the needle indicating the two terms of a ratio the numbers brought under these points will be in the same ratio.

Remark : The similitude of the movements explained in the three preceding rules shows that multiplication and division are proportions in which one of the terms is unity.

## Examples.

1st. If £24 is the price of an object and one asks the price of thirty-two objects, one must either work out the multiplication $24 \times 32 = x$ or resolve the proportion $1 : 24 :: 32 : x$. In this case, therefore, one brings 24 under the index and places the needle on 1, we have thus two terms of a ratio indicated, the one by the needle and the other by the index, and one says : if 1 object indicated by the needle costs £24 indicated by the index, the number of 32 objects which one brings under the needle will cost £768 and this result will be indicated by the index. The needle whilst indicating any number of articles whatever, the index points out the price of these articles.

2nd. If one asks the price of one article knowing that 32 cost £768. One will have to perform the division $768 : 32 = x$ or solve the proportion $32 : 768 :: 1 : x$. The problem is solved thus. Bring 768 under the index and place the needle on 32. We shall have two terms of a ratio, the one indicated by the needle and the other by the index and one reasons thus : if 32 articles, indicated by the needle cost £768 indicated by the index, one object led under the needle the cost £24 wille be pointed out by the index. Under the needle are always the unities of the same nature and this is also the case under the index. In this example the needle having indicated the articles the index has served to indicate the number of £'s.

3rd. If we know that the price of an object is £24 and one asks how many articles we should receive for £768 we can perform the division $768 : 24 = x$ or solve the proportion $24 : 1 :: 768 : x$. Therefore we bring 1 under the index, place the needle on 24 and have then two terms of a ratio, indicated, the one by the needle and the other by the index. We reason thus: if for £24 indicated by the needle one receives 1 article indicated by the index, for £768, which number we bring under the needle one receives 32 articles which number the index points out for us. In this example the needle having served to indicate £'s, the index serve to indicate the number of articles.

*The advantage existing by operating in such a manner that the result will be shown by the index, in calculations made with the moveable dial only.*

In the third example above one could have proceeded, as in the two preceding examples, to indicate the articles by the needle and the £'s by the index. Then the result would have been indicated by the needle, but it is preferable to operate in such manner as to obtain the result pointed out by the index. Experience will show that it is easier and surer to adopt this method which does not tend to make one hesitate as to the choice between the needle and the index, if one works sometimes in one way, sometimes in another.

There is, on the other hand, a great advantage by performing the multiplications and divisions according to the rule given above, which give the solutions of these operations indicated by the index, because in doing so, one is able to solve a numerical formula containing the indication of several multiplications and divisions, without keeping count of the products and partial quotients of the different operations successively performed. Suppose it is necessary to solve the formula

$$\frac{\pi \times 0,32^2 \times 8,25 \times 1170}{4} = x$$

$x$ being the required weight of a cylindrical piece of wood of 0,32 diameter, 8,25 lenght, in oak the specific gravity of which is 1170.

Following the rules given we bring $\pi = 3,1416$ under the index and place the needle on 4. Then bring 32 under the needle—that is 32 on the scale of squares—and bring the ne dle on 1. Then again one brings 8,25 under the needle and return the needle to 1, finally, bring 1170 under the needle and the index will indicate $x = 776^k$ (The calculation by the ordinary methods gives $776^k$ 30).

By operating otherwise we can obtain the same result but more showly because it would be necessary to keep count of all the partial results of operations performed successively.

Indeed, if to multiply 3,1416 by $0,32^2$ one places the 1 of the dial at the index in order to place the needle on 3,1416 and lead $0,32^2$ under the index, it would be necessary to read and carry over to the index, the product, indicated by the needle, of this first multiplication in order to continue the calculation. It would be the same for each of the other operations though it would be prejudiciable to rapidity of calculation and would increase the chances of error.

But this recommendation to act in this manner of always obtaining results of operations indicated by the index, is only to be followed when one works with the moveable dial. One will see, further on, that when calculations on the scale of the cubes, on the fixed dial are necessary, one is often obliged to indicate the results of operations by the needle.

*Multiplication or Division by a Square or a square Root.*

For the formula $x=av^2$ or $x=a^2v$ or $x=a^2v^2$ in which $v$ is variable, one brings a under the index by taking a in the s[illegible] numbers or that of squares according as the case may be, and one places the needle on 1. Then lead $v$ under the needle, by taking $v$ equally, as the case may be, on the scale of numbers or on that of the squares. Than for each value of $v$ under the needle will correspond a new value of $x$, indicated by the index.

For $x=v : a^2$ or $x=v^2 : a$ or $x=v^2 : a^2$ one brings the 1 under the index and carries the needle on $a$ or $a^2$, then for each value of $v$ or $v^2$ led under the needle will correspond a new value of $x$, under the index.

For $x=v\sqrt{a}$ or $x=v^2\sqrt{a}$. One brings a of the scale of numbers under the index and read its root on the scale of squares, then bring this root, found on the scale of numbers, under the index. Then for each value of $v$ or $v^2$ led under the needle will correspond a value of $x$ under the index.

For $x = \sqrt{b}\sqrt{a}$, after having brought $\sqrt{a}$ under the index and carried the needle to the 1 one places under the needle $b$ on the scale of numbers and reads its square root on the scale of squares. Then one brings this root under the needle when $x$ will be indicated by the index.

For $x = v : \sqrt{a}$ or $x = v^2 : \sqrt{a}$, after having led 1 under the index, one turns the needle on a of the scales of numbers and reads its root on the scale of squares. Then one turns the needle to this root on the scale of numbers and for each value of $v$ or $v^2$ brought under the needle will correspond a value of $x$ indicated by the index.

For $x = \sqrt{b} : \sqrt{a}$, after having brought 1 under the index and pointed the needle on $\sqrt{a}$, one brings $b$ of the scale of numbers under the needle and reads its root on the scale of squares. Then this root is brought under the needle on the scale of numbers, and $x$ will be indicated by the index.

*Multiplication or Division by a Cube or Cubic Root.*

For $x = av^3$ or $x = a^2v^3$ or $x = v^3\sqrt{a}$ one brings a, $a^2$, or $\sqrt{a}$ under the index. Then one carries the needle to $v$ on the scale of cubes and for each value of $v$ will correspond a value of $x$ indicated by the needle on the scale of numbers.

For $x = va^3$ or $x = v^2a^3$ one brings the needle to $a$ on the scale of cubes and for each value of $v$ or $v^2$ brought under the index, will correspond a value of $x$ indicated under the needle.

For $x = a^3 v^3$, one brings the needle to $a$ on the scale of cubes and reads the cube on the scale of numbers. Then one brings this latter cube under the index and pointing the needle to $v$ on the scale of cubes for each value of $v$ will correspond a value of $x$ indicated by the needle on the scale of numbers.

For $x = v : a^3$ or $x = v^2 : a^3$, one brings the needle on $a$ of the scale of cubes and for each value of $v$ or $v^2$ that one brings under the needle corresponds a value of $x$ under the index.

For $x = \sqrt{b} : a^3$, one turns the needle to $a$ on the scale of cubes and after finding the value of $\sqrt{b}$ as in the example given above, one places this root under the needle on the scale of numbers. Then $x$ will be indicated by the index.

For $x = v^3 : a^3$ one turns the needle [illegible] the scale of cubes and brings the 1 of the moveable dial under the needle. Then for each value of $v$ indicated by the needle on the scale of cubes, will correspond a value of $x$ indicated on the scale of numbers by the needle.

For $x = v\sqrt[3]{a}$ or $x = v^2\sqrt[3]{a}$ one brings $\sqrt[3]{a}$ under the index and places the needle on 1, then for each value of $v$ or $v^2$ under the needle there will be represented a value of $x$ under the index.

For $x = v^3 \sqrt[3]{a}$, one brings $\sqrt[3]{a}$ under the index and for each value of $v^3$ of the needle will correspond a value of $x$ indicated by the needle on the scale of numbers.

For $x = v : \sqrt[3]{a}$ or $x = v^2 : \sqrt[3]{a}$, one brings 1 under the index and turns the needle on $\sqrt[3]{a}$.

Then for each value of $v$ or $v^2$ that one brings under the needle will correspond a value of $x$ under the index.

The limited outline of these instructions does not permit of the indication of all the formulæ which containing powers or roots to the second and third degree, can b· solved by m ans of the instrument. The explanation which precedes will be sufficient to indicate the methods to follow, and shows that with the calculating circle, one is able to introduce into calculations with as great an ease as with ordinary numbers and without mistake: squares, cubes, square roots, and cube roots.

*Square Root of a Cube or Powers 3/2.*

For $x=\sqrt{v^3}=v^{3}/_{2}$ one brings the 1 of the moveable dial under the index and for each value of $v$ indicated by the needle on the scale of cubes, will correspond a value of $x$ indicated by the needle on the scale of squares.

*Cube Root of a Square or Power 2/3.*

For $x=\sqrt[3]{v^2}=v^2/_{3}$, one brings the 1 of the moveable dial under the index and for each value of $v$ indicated by the needle on the scale of squares will correspond a value of $x$ indicated by the needle on the scale of cubes.

## Logarithms.

To find the logarithm of any number $v$ whatever, the 1 of the dial being under the index one brings the needle to $v$ on the scale of numbers and reads the decimal part of the logarithm on the exterior circle of the fixed dial.—As to the characteristic, one knows that it contains as many units as there are figures less 1, in the entire part of the number, and that for numbers smaller than 1, the characteristic negative indicates the rank of the 1st significant figure of the number, after the coma. For 0,1 it is 1, for 0,01 it is 2 etc.

Reciprocally to find the corresponding number to a given logarithm, one brings the needle to the decimal part of that logarithm, taken on the exterior circle of the fixed dial and, the 1 of the moveable dial being at the index, the needle will indicate on the scale of numbers the first significant figures on the left of the required number, whilst the characteristic will indicate, moreover, the order of the units of these figures.

### *Any Powers and Roots Whatever.*

For $x = a^n$, one takes the log. of a, one multiplies it by $n$ and then one finds the number $x$ corresponding to the log. obtained in the product.

For $x = \sqrt[n]{a}$, one takes the log. of $a$, divides it by $n$ and finds the number $x$ corresponding to the log. obtained in the quotient.

### *Number of Figures in the Product of a Multiplication and Determination of the last Figure of this Product.*

The product of a multiplication ought to have as many figures as the two factors together, or one less. There are as many when the first significant number is smaller in the product than in the factors, there is one less in the contrary case.

For the decimal numbers, the numbers of figures ought only to be understood for the entire part: 34,50 to 2 figures, 3,45 to 1 figure, 0,65 to no figure, 0,035 to less than 1 figure, 0,008 to less than 2 figures, etc., counting the figures as less if there is a 0 after the comma.

The last figure of the product of two numbers, is the same as the last figure of the product of the last figure of the one by the last figure of the other.

*Examples :*

$x=24\times32$.—One sees that the 1st significant figure of $x$ is $7 > 2$ or 3, $x$ will have then three figures and one reads by the index 768 with certainty knowing that the product ought to terminate with an 8

$x=46\times27$.—One sees that the 1st significant figure of $x$ is $1 < 4$ or 2, $x$ will have then four figures and one reads by the index 1242 with certainty, knowing that $x$ ought to terminate with a 2.

$x=1,40\times0,025$.—One sees that the 1st significant figure of $x$ is $3 > 1$ or 2, $x$ will have then a figure less than the two factors together, which have : the 1st, one and the 2nd less one, that is to say it will be —1, because one has $(1-1)-1=-1$. This product will not have then an entire part and there will in addition be a zero after the comma, one reads in consequence 0,035.

## *Number of Figures in the Quotient of a Division.*

The number of figures in the quotient of a division ought to be equal to the figures of the dividend, less the number of figures of the division, or ought to be equal to that difference plus 1. Since the 1st significant figure is greater in the division than in the dividend, it is necessary to take the difference only, in the contrary casé it is necessary to augment it by 1.—Since the 1st figures are the same, one compares the following.

*Advantage in the Employment of Divisors.*

Again taking the formula solved higher up.

$$x=\frac{\pi\times 0,32^2\times 8,25\times 1170}{4}$$

one notices that we can replace the multiplicator $\pi=3,1416$ by the divisor $\frac{1}{\pi}=0,3183$ and replace this formula by the following.

$$x=\frac{0,32^2\times 8,25\times 1170}{0,3183\times 4}$$

Finding the value of $x$ by this formula one sees that the substitution effected diminishes the number of movements of the dial or needl[illegible]s.—But this formula ca[illegible] [illegible] simplification, if one con[illegible] [illegible] multiplicator 1170 and the divisors 0,3183 and 4 exist in all the formula giving the weights of pieces of wood of the same material not varying except as regards squareness and lenght. Replacing

$\frac{1170}{0,3183\times 4}$ by its equivalent $\frac{1}{0,001088}$

the formula takes this new form

$$x=\frac{0,32^2\times 8,25}{0,001088}$$

which only requires a multiplication and a division.

In the employment of the calculating circle for the solving of geometrical formula one will find in mathematical works the divisors employed to facilitate calculation.

## Trigonometry.

The 1 of the moveable dial being under the index. If one turns the needle on any point whatever of the sca'e of sines, on that. for example marking the angle $a=26°20'$ one reads there at first sight its complement $a'=63°40'$ and the needles will indicate : on the sca'e of numbers the natural sine of $a=0,444$ and on the exterior scale of the fixed dial, the decimals of the logarithm 1,647 of that sine.

To read the natural sines indicated on the scale of numbers one will remember that the sines of the angles from 0° to 0°4' are comprised between 0 and 0.001, that those from [illegible] 0°[illegible] are between 0.001 and [illegible] those fr[illegible]m 0°35' to 5°45' are between 0.[illegible] and 0.1 that those from 5°45' to 90° are between 0.1 and 1.

The scale of the sines being on the moveable scale suffices for the resolution of all cases of triangle by means of formulæ.

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FIELD DIAL

Exactitness Guaranteed