J. W. Nystrom.

Calculating Mach.

No. 7,961. Patented Mar. 4, 1851.

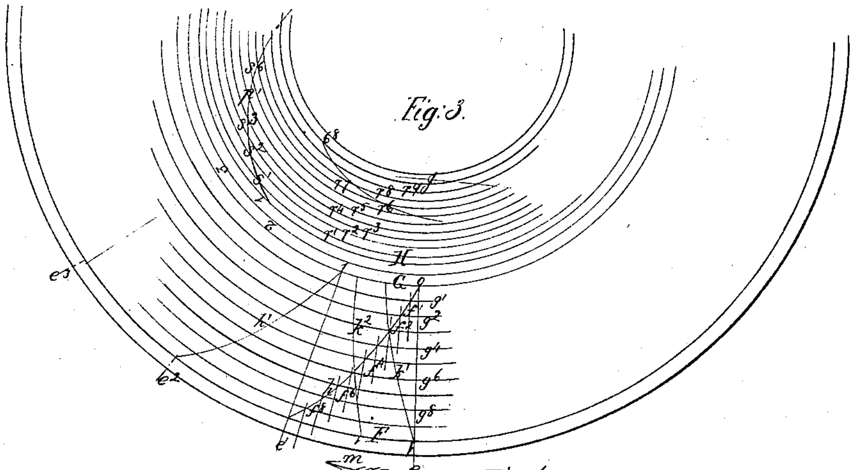


Fig: 3.

Fig: 1.

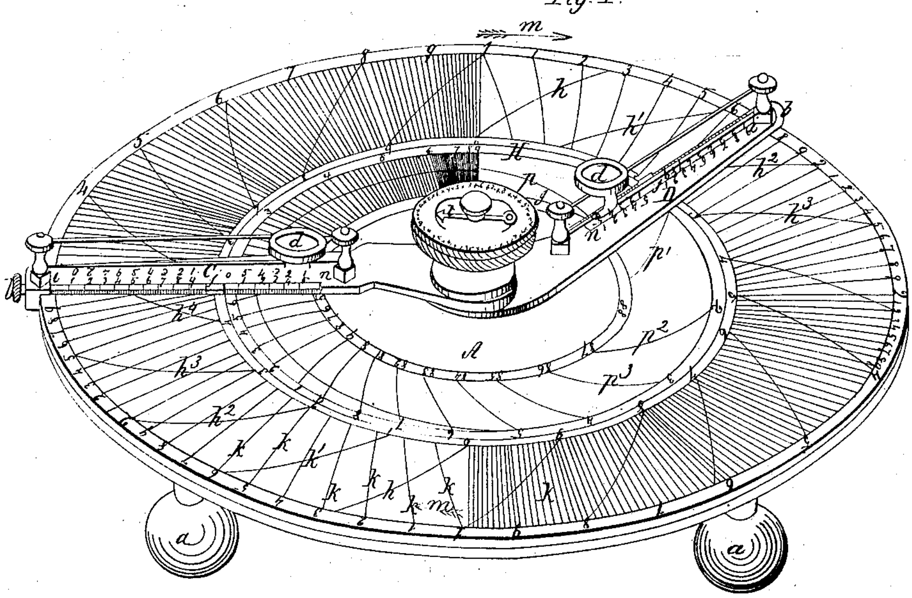
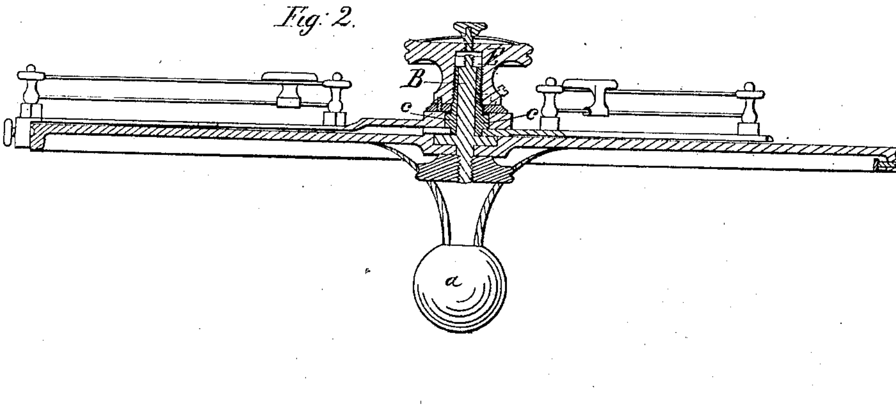


Fig: 2.



UNITED STATES PATENT OFFICE.

J. W. NYSTROM, OF PHILADELPHIA, PENNSYLVANIA.

CALCULATING-MACHINE.

Specification of Letters Patent No. 7,961, dated March 4, 1851.

To all whom it may concern:

Be it known that I, John William Nystrom, of the city and county of Philadelphia and State of Pennsylvania, have invented a new and useful Calculating-Machine, of which the following is a full, clear, and exact description, reference being had to the accompanying drawing, which forms part of this specification, and in which—

Figure 1 is a view in perspective of one of my machines. Fig. 2 is a vertical section through the center of the same, and Fig. 3 is a plan of a portion of the disk showing the method of laying out the curved lines.

My invention is based upon the fact that the multiplication and division of numbers may be performed by the addition and subtraction of their logarithms, and my machine is constructed in such manner that this addition and subtraction is effected by moving a pair of graduated radial arms upon a disk on whose surface a series of curves are drawn, which by their intersection with the arms show the value of the result. The curves on the disk in combination with the radial arms serve, not only to effect ordinary arithmetical calculations but also to solve trigonometric formulae.

The machine, as represented in the accompanying drawing, consists of a disk A of metal or some other suitable material which is mounted upon three feet *a*, *a*, *a*. An upright spindle B is secured at its center on which the hubs of two radial arms C, D, are constructed to turn. These arms extend to the periphery of the plate, their outer extremities being fitted with clamp screws *b* *b* by means of which they can be made fast in any required position. The hub of one arm is fitted to a sleeve *c* on which the hub of the other turns freely; the latter is surmounted by a clamp nut E which is screwed upon the sleeve *c* so that by tightening or slacking it the hubs of the two arms can be clamped to each other or can be left free to turn independently. As the divisions on the radial edges of the arms are fine each arm is furnished with a magnifying glass *d* which is constructed to slide freely along it so that it may be shifted from one position to another to read any division of the arms.

Two series of curved lines or scales are drawn upon the surface of the disk, the outer scale being for the addition, subtraction, multiplication and division of numbers while the inner is for effecting the same operations with the trigonometric functions. Each scale consists of a series of spiral curves which are contained between two concentric circles. The outer scale contains two varieties of spiral lines which run in opposite directions, the one I term diagonals, the other logarithmic curves.

In order to draw the lines of the outer scale, commence by drawing the two concentric circles F, G, which bound the scale; divide the inner circle G into a number of equal parts, which number must be a multiple of ten; and each ten of which constitute a complete scale, the other sets of ten being exact duplicates of the first. In the instrument represented in the accompanying drawings the circle G is divided into twenty equal parts (10×2) which are numbered 0, 1, 2, 3,—9; 0, 1, 2, 3,—9; through the divisions 1, 2, &c., of the circle draw the radial lines *e* *e′* &c., and subdivide the arc of the circle between the radial lines *e* *e′* into ten equal parts, through which draw the secondary radial lines f', f^2, &c. Divide any one of the radial lines (f') into ten equal parts and through the divisions draw the concentric circles, g', g^2, &c. Unite the points of intersection of the radial lines *f* and circles *g* by a curved line *h* which line will be the diagonal line of the scale. All the diagonals of the scale are alike and when one is obtained the others can be drawn from it.

That portion of the radial edge *i*, *j* of each arm C, D, which is contained between the two concentric circles F, G, is divided into ten equal parts, which are numbered (0, 1, 2, 3—9) both from within outward and from without inward; each of these larger divisions is subdivided into ten equal parts, and if greater nicety is required in determining the results, each of these subdivisions may be divided into tenths. The logarithmic curves *k* of the outer scale are drawn from without inward, the first curve *k* starts from that point *l* in the outer circle where it is intersected by the radius which passes through the 0 point on the inner circle, G. In order to obtain the other points of the curve recourse must be had to a table of logarithms; commence with the logarithm of 11. This is .0414, move the radial arm C from the 0 point of the scale in the direction indicated by the arrow m until the diagonal h intersects that division on the arm which counting from within outward denotes the number .0414, or 0 of the large divisions on the inner circle G, 4 of the large divisions on the arm C and $1\frac{4}{10}$ of the subdivisions. When the radial arm is at this position the point where its radial edge intersects the inner circle G is the stopping point of the first logarithmic curve, while the point where the radial edge intersects the outer circle F is the division 1 or the starting point of the second logarithmic curve.

The intermediate points of the first curve are found by taking the logarithms of 10.1, 10.2, 10.3—10.9, and setting the arm in succession in the positions in which the diagonal line h intersects the divisions on the radial edge which correspond with the logarithms of these numbers; those points in the concentric circles g'—g^9, where the radial edge of the arm successively crosses them will be the intermediate points through which the logarithmic curve is drawn. The stopping point of the second logarithmic curve k^2 is formed by moving the arm C in the direction of the arrow until the diagonal line corresponds with that division on the arm which denotes the logarithm of 12; and the intermediate points are found in the same manner as those of the first curve by taking the logarithms of the numbers 11.1, 11.2, 11.3, &c. The other logarithmic curves are laid out in the same manner as those above described and if great accuracy is desired a greater number than 10 of the intermediate points should be determined.

From the above description it will be perceived that the numbers on the inner circle and on the arm counting outward, denote the logarithms of the corresponding numbers on the outer circle and arm counting inward. Thus if the arm be set at the small division 2 of the outer circle which denotes the number $1\frac{2}{10}$ or 12, the number .0792, where the diagonal line h crosses the edge of the arm, is the logarithm of 12.

The inner scale contains but one variety of curves, these are laid out in a manner similar to that described in laying out the curves of the outer scale. As angles are measured by the degrees of the arc of the circle subtended by their radii, and as these degrees are subdivided into sixty equal parts, generally called minutes, it is necessary to divide those portions n, o of the radial edges of the arms C, D, which are contained between the bounding circles H, I of the scale, into sixty equal parts, each of which denotes $\frac{1}{60}$ of a degree or one minute and if the dimensions of the scale are sufficient these minute divisions should be subdivided into fractional parts. As the disk of the instrument represented in the accompanying drawing is of small size, it was convenient to construct the inner scale single, instead of double as was the case with the outer scale.

The curves of the inner scale are laid out by the aid of the outer scale and the graduated arms. As the outer scale is double, one semicircular portion of 10 divisions may be taken for units while the divisions of the other portion will represent the decimal fractional parts of a unit. The curves p are for the purpose of finding the sines and cosines of angles, from which the other trigonometric functions can easily be determined. In order to find the starting points of the curves recourse must be had to a table of natural sines; commence with the sine of one degree (1°) this is .01745, move the arm C from the 0 point of that portion of the outer scale which is to be used for the fractional parts of a unit, in the direction indicated by the arrow m, until the divisions 1 and $\frac{7}{10}$ on the outer circle F are passed and the division $4\frac{5}{10}$ on the arm (counting from without inward) intersects the logarithmic curve, leading from the division $\frac{7}{10}$; then that point in the circle H which is cut by the radial edge of the arm is the division 1 whence the trigonometric curve p' is drawn; and that point where the radial edge of the arm crosses the inner circle I is the division 89 where the curve p stops by means of which the sines of the fractional parts of the angle of 1° are determined. In order to find the division 2, take from the table the natural sine of two degrees (2°) .03480, and move the arm in the direction of the arrow m (which I shall henceforth call forward) until the division $3\frac{4}{10}$ on the outer circle F is passed and the division (8) on the arm, intersects the appropriate logarithmic curve; then the point where the radial edge of the arm crosses the inner circle I is the division (88) where the trigonometric line p' stops; while the point where the radial edge of the arm crosses the outer circle H is the division (2) whence the second trigonometric line p^2 starts. The corresponding starting and stopping points for the other trigonometric lines 3, 4, 5, &c. are determined in the same manner by taking the natural sines of 2°, 3°, 4° &c. The intermediate points of each trigonometric curve, are formed by drawing a series of concentric circles r' r^2—p^9, and by taking from a table the natural sines of those minutes which fall between each degree and the next succeeding one; thus for the line p', if nine concentric circles be used, the natural sines of 1°.6′, 1°.12′, 1°.18′, 1°.24′, 1°.30′,—1°.54′ must be taken and the arm C is set in succession to those positions on the outer scale which indicate numbers corresponding with the natural sines of these angles. Then the points s', s^2, s^3, s^4, &c. where the arm successively crosses the concentric circles r will be the intermediate points through which the curve p' is to be drawn. The intermediate points of the remaining curves are found in the same manner. If great accuracy be required a greater number of intermediate points must be determined. As the cosine of an angle is equal to the sine of its complement the divisions on the inner circle I and on the arm counting outward will denote the angles of which the numbers indicated by the corresponding divisions on the outer scale are the cosines.

As before mentioned the principle on which my machine is based is that the multiplication and division of numbers can be performed by the addition and substraction of their logarithms. Hence in calculating with the machine it is convenient to have some place where the indexes of the logarithms can be minuted down. This is effected by a dial on the clamp nut E which is traversed by a movable hand t, which can be moved freely from one division of the dial to another. The divisions are numbered in opposite directions from a 0 point, the + divisions indicating that the number calculated is greater than unity, and the— divisions indicating that it is less than unity.

In the above description I have supposed that the various lines on the disk are drawn by hand but in manufacturing calculating instruments for sale I propose to construct machines for drawing the lines by the aid of mechanical devices.

The instrument thus constructed can be used for the addition and subtraction of numbers. When used for this purpose the one arm C is clamped by the screw b at the 0 point of the circle G. The other arm D is then moved forward until the divisions on the inner circle G and on the arm D (counting outward) which are cut by the appropriate diagonal line correspond with one of the numbers to be added. The two arms are now clamped together by turning the clamp nut E, the clamp screw of the arm C is slackened and the two arms clamped together are moved forward until the divisions on the circle G and on the arm C (counting outward) which correspond with the second number to be added are cut by the appropriate diagonal line; then the division on the arm D cut by the appropriate diagonal line, and on the inner circle G show the sum of the two numbers. Thus suppose that 25 is to be added to 32; set the arm C at 0, the arm D at 25, clamp the two; move the two so clamped past the division 3 on the circle G until the arm C is in such a position that the diagonal line cuts the division 2 (counting outward). Then the division 7 on the arm D cut by the diagonal line preceded by the division 5 of the circle G last passed by the arm D, show the sum 57 which is the result sought. If a third number, 20 for example, is to be added to the sum thus found clamp the arm D in its position, slacken the nut E and move the arm C back to 0. Clamp the two arms together, unclamp the arm D, and move the two until the arm C arrives at the division 2 on the inner circle, then the division (7) on the arm D cut by the diagonal line, preceded by the number of the division (7) on the inner circle last passed by the arm D show the sum sought which is 77.

It will be perceived from the above that the operation of addition is effected by increasing the angle included between the two arms in arithmetic proportion to the sums to be added: Subtraction is the reverse of addition hence it is effected by diminishing this angle in arithmetic proportion. Thus for example let us suppose that 20 is to be subtracted from 97. Set the arm D at 97, and the arm C at 20; clamp the two, and move them so clamped backward (that is in a direction the reverse of the arrow) until the arm C arrives at the 0 point. Then the division (7) on the arm D cut by the diagonal line preceded by the next division (7) on the inner circle shows the remainder, 77, sought.

When multiplication is to be performed it is effected by increasing the angle between the two arms in proportion to the sums of the logarithms of the numbers. Thus, to multiply 245 by 122, move the arm D forward past the division $2\frac{4}{10}$ on the outer circle F until the division 5 on the arm (counting inward) is cut by the logarithmic curve, and clamp it in this position; as the logarithmic index of 245 is 2 the hand t must be moved to the division + 2 on the dial, add to this the index 2 of the multiplier (122) making + 4. Place the other arm C at the division 1 on the outer circle, clamp the two arms together and move them so clamped forward until the arm C has passed the divisions $1\frac{2}{10}$ of the outer circle, and the appropriate logarithmic curve cuts the division 2 on the arm. It will now be found that the division on the arm D cut by the logarithmic curve is $8\frac{9}{10}$, which preceded by the divisions (29) on the circle F passed by the arm, gives the fig. 2989 of the products, and as the index is + 4 the number is 29890. If this product is to be multiplied by a second multiplier, the arm D is clamped at its position and the arm C is moved back to the starting point (1) of the scale; the two are now clamped and moved in connection until the proper division of the arm C is cut by the appropriate logarithmic curve. The division of the arm D then cut by the appropriate logarithmic curve, preceded by the figures of the divisions of the circle F passed over show the figures of the new product. Whenever in moving the clamped arms the forward one passes the dividing point of the double scale, the logarithmic index is increased by 1, and hence this increase must be minuted by moving the hand t on the dial.

As division is the reserve of multiplication, it is found by diminishing the angle between the two arms. The arm D is set at the division of the scale corresponding with the dividend, and the arm C is set at that of the divisor; the two are then clamped and moved backward until the arm C reaches the starting point of the scale, when the divisions of the arm D preceded by the figures on the outer circle, will show the quotient.

If the logarithm of a number is required it is found by setting one of the arms to the division on the outer circle and arm which corresponds with the number. The division on the arm counting outward cut by the diagonal line and preceded by the figures of the divisions on the circle G passed by the arm in moving from the starting point is the logarithm required.

If a root is to be extracted, as for example the cube root of 27, set one of the arms at that number on the outer circle F. The corresponding number (31) on the arm counting outward cut by the diagonal line and preceded by the number of the division (4) last passed by the arm will then be the logarithmic number of 27 or 431, the logarithmic index of 27 is 1 and the whole logarithm is consequently 1.431; divide this by the exponent of the root 3, making 0.477, and set one of the arms to this logarithm. Then the corresponding divisions 300 on the outer circle and arm are the figures of the root sought, and as its index is 0, the number is 3. Powers, as squares, cubes, &c., are found by reversing this operation or by first finding the logarithm of the number, multiplying it by the exponent and setting one of the arms to the new logarithm, when the number indicated by the outer circle and arm counting inward is the power sought.

The inner scale is used to find the sines and cosines of angles, and when these are found to determine from them the other trigonometric functions by the usual formulæ. It is also used to multiply or divide trigonometric functions, in which case the operation is effected by moving the arms in the same manner as when multiplying or dividing numbers on the outer scale. The result of the operation is indicated by the divisions on the outer circle of the outer scale and the divisions of the arm counting inward, and the logarithm of the result is shown by the corresponding divisions on the inner circle of the outer scale and the arm counting outward.

The instrument can be used to solve many of the usual trigonometric formulæ; thus let it be required to solve the equation

$$\text{sin. C} = \frac{c \text{ sin. B}}{b}$$

the values of c B and b being as follows: $c=170+$ $\text{B}=25°$ $b=112+$; set the arm C at the starting point and move the arm D forward to the position corresponding with the number 170; clamp the two arms together; set the finger t to the proper index $+2$. Now move the two arms forward until the arm C arrives at the position corresponding with the sine of 25° as shown by the divisions on the outer circle H of the inner scale, clamp the arm D, slacken the clampnut E and set the arm C to the position corresponding with the number 112; reclamp the two arms and as the logarithmic index of 112 is $+2$ this must be subtracted from the number pointed at by the finger on the dial leaving 0 for the index of the result. The two arms now clamped must be moved backward until the arm C arrives at the starting point when the number of the divisions on the inner scale indicated by the arm D is the angle C required or 39°, 53′.

The above examples are sufficient to enable persons skilled in arithmetical and trigonometrical calculations to use my machine and I therefore deem it unnecessary to give others.

In order to facilitate the working of the machine I have fitted a spring stop v to the disk at the starting point of each scale, so that in setting the arm at this starting point all that is necessary is to bring it in contact with the stop.

I have thus far described the logarithmic curves as curving forward as they extend from the outer circle toward the center of the scale, while the diagonals curve forward as they extend from the inner circle outward. This arrangement of the two curves is merely one of convenience for it is evident that the same results can be obtained by reversing the directions of drawing the two curves; that is to say by making the logarithmic curves start from the inner circle and the diagonals from the outer one. The figures on the inner divisions would then denote the numbers while those on the outer circle would denote their corresponding logarithms. It is also evident that instead of laying out the curves of the inner scale by means of a table of natural sines and the outer divisions of the outer scale, recourse may be had to a table of logarithmic sines, in which case the arm must be set to its place by the inner divisions of the outer scale which denote the logarithmic numbers corresponding with the natural numbers of the outer divisions.

What I claim as my invention and desire to secure by Letters Patent is—

1. The logarithmic curves of the outer scale in combination with the diagonals and graduated arms, the curves being laid out substantially in the manner herein set forth.

2. I claim the trigonometric curves of the inner scale in combination with the graduated arms and logarithmic curves of the outer scale, the curves being laid out substantially in the manner herein described.

3. I claim the two graduated arms constructed in such manner that they can be moved in connection or independently substantially in the manner and for the purposes herein set forth.

In testimony whereof I have hereunto subscribed my name.

J. W. NYSTROM.

Witnesses:
P. A. Watson,
E. S. Rennick.