XXX. On a machine for calculating the products, quotients, logarithms, and powers of numbers

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rise to crystallization, like those of frost and of congealed water. Although we have rarely seen it in a liquid state, yet during summer, under the influence of the sun's rays, its crystals become perfectly liquid and assume a globular form, and which they retain as they again solidify; forming, in these cases, conditions corresponding to water in a liquid state, ice and sleet.

XXX. *On a Machine for Calculating the Products, Quotients, Logarithms, and Powers of Numbers.* By the Rev. HENRY MOSELEY, M.A., F.R.S., one of Her Majesty's Inspectors of Schools, and lately Professor of Natural Philosophy and Astronomy in King's College, London*.

[With a Plate.]

I HAVE proposed to myself in the construction of this machine, to determine mechanically the products, quotients, logarithms, squares, square roots, and other powers and roots of the natural numbers, by means of combinations of greater simplicity than have hitherto been applied to the purposes of mechanical calculation.

The accompanying Plate II. is intended to illustrate the *principle* of the machine, but it does not show the mechanical details of its construction or the due proportion of its parts.

It will be observed that it consists principally of a cone and a screw. The application of the cone and the disc to various purposes of mechanical calculation has long been well known, and particularly by the ingenious applications made of the disc to dynamical admeasurement by MM. Poncelet and Morin.

The novelty of *this* instrument consists in the combination of the screw with the cone.

CD represents a small screw terminated by solid cylindrical axes or gudgeons, of which that shown by the letter D is prolonged, and carries an index T. The screw admits of being fixed in its bearings or made to revolve in them.

PQ is a wheel having a hollow cylindrical axis, into which is accurately fitted a hollow cylindrical piece, whose internal surface is traversed by the thread of a female screw working upon the male screw CD.

The hollow axis of the wheel PQ admits of being fixed upon the cylindrical piece inserted in it, or of being disengaged from that piece, so that the wheel PQ may be made to carry the female screw round with it in its revolutions, or to turn freely upon the outside of the cylinder which contains that screw, as upon an axis.

* Communicated by the Author.

The three arms of the wheel PQ are pierced by apertures, through which pass, accurately fitting them, the three rods of the rigid frame EF, which frame turns in fixed bearings at C and D upon hollow axes, through which axes pass the cylindrical extremities or gudgeons of the screw CD.

The wheel PQ traverses the frame EF longitudinally, and at the same time carries it round with it in its revolutions: and it admits of being *fixed* upon the frame at any distance from either extremity. The frame carries an index S.

AGH is a cone, whose side AG is parallel to the screw CD, which turns by means of a spindle AB upon fixed bearings, and which is continually pressed upon the edge of the wheel PQ by a spring acting upon the extremity of its spindle. The cone is of some soft metal, brass for instance. The edge of the wheel PQ is very thin, of steel, and milled, so that it imprints a minute tooth upon the soft face of the cone at every point where it revolves in contact with it.

The spindle AB carries an index R. The indices R, S, T point to equidistant divisions upon fixed circles, not shown in the Plate; and each of them is connected with a train of wheels and pinions, whose numbers of teeth are in the proportion of ten to one, and which serve to measure the complete number of revolutions and parts of a revolution made by each index.

Now certain dimensions (hereafter to be determined) being assigned to the different elements of this combination, it may be shown,—

1st. That if the frame EF be fixed, and the screw CD turned until the index T points to any given number N_3 , and then the frame be released, the wheel PQ *fixed* upon the frame, and the cone turned until the index R points to any other given number N_1 , then will the index S point to the product of the numbers N_1 and N_3 .

2nd. That if, as before, the frame EF be fixed, and the screw turned until the index T points to any number N_3 , and then the wheel PQ be *fixed* on the frame, the frame released, and the cone turned until the index S points to any other number N_2 , then will the index R point to the *quotient* of N_2 by N_3 .

3rd. That if the *screw* CD be fixed, the wheel PQ and the frame released, and certain other adjustments made, and if the cone be turned until the index S points to any number N , then will the index R point to the *logarithm* of that number.

4th. That if the spindle of the cone be connected with the axis of the screw CD by means of two bevelled wheels, so that the rotation of the one shall always bear a given relation to that of the other, then the frame EF and the wheel PQ being

both released, and the cone turned until the index R points to any number, the index S will point to the *square* of that number.

Theory of the Instrument.

Let ρ be taken to represent half the angle at the apex of the cone, ρ the radius of the wheel PQ, and λ the distance between each two threads of the screw; also let n_1, n_2, n_3 represent severally the numbers of equidistant divisions on the circles to which the indices R, S, T severally point; then will $\frac{N_1}{n_1}, \frac{N_2}{n_2}, \frac{N_3}{n_3}$ represent the numbers of revolutions made severally by the indices whilst the numbers N_1, N_2, N_3 are registered. Now suppose that when the wheel PQ is at the apex of the cone the indices R, S and T each point to zero, and the frame EF being fixed, let the screw CD be turned until the index T shows the number N_3 ; then will the screw have made $\frac{N_3}{n_3}$ revolutions, and the wheel PQ will have advanced from the apex of the cone to a distance AP from it, represented by $\frac{N_3}{n_3} \cdot \lambda$; so that the radius PM of the circle described by that point whilst the cone revolves will be represented by $\frac{N_3}{n_3} \lambda \sin \iota$, and its circumference by $2\pi \frac{N_3}{n_3} \lambda \sin \iota$. Now let the cone be made to revolve (the wheel PQ being fixed upon the frame and the frame released) until the index R shows the number N_1 , or until the cone has made $\frac{N_1}{n_1}$ revolutions; then will the point P in it have been made to revolve through a space represented by

$$2\pi \frac{N_3}{n_3} \cdot \lambda \sin \iota \cdot \frac{N_1}{n_1},$$

or by
$$\frac{2\pi \lambda \sin \iota}{n_1 n_3} \cdot N_1 N_3.$$

But by reason of the continual pressure of the cone upon the edge of the wheel PQ, that wheel will have been carried round in the revolution of the cone, so that the circumference of the wheel will have described precisely the same space as the point P of the surface of the cone; if therefore N_2 represent the number pointed to by the index S, so that $\frac{N_2}{n_2}$ represents the number of revolutions made by the frame EF and wheel

then
$$N_4 = N_1^8, \dots \dots \dots (6.)$$

and
$$N_1 = \sqrt[3]{N_4}; \dots \dots \dots (7.)$$

so that (under this combination) the number N_4 shown by the index of the second frame is, in every position, the cube of that shown by the index R; and conversely, the number shown by the index R is the cube root of that shown, at the same time, by the index of the second frame.

In like manner, by placing any number of like systems of a frame, screw and wheel, upon the side of the cone, the third screw receiving its motion from the second frame, the fourth from the third, &c., any other powers of the number N_1 , or roots of the numbers N_2 , N_4 , &c. may be conceived to be determined, the power shown by the last index, or the root by the first, being one greater than the number of frames so applied.

The four equations of condition ($\alpha.$), ($\beta.$), ($\gamma.$), ($\delta.$) between the nine quantities $n_1, n_2, n_3, n_4, n, n', \lambda, \iota, \rho$ leave five of them undetermined. These are to be assumed of such values as may be found most convenient in the construction of the machine, the *general principle* of which it is the object of this paper to explain.

The Plate in particular, as has already been stated, is by no means intended to show the details of the construction of the machine, or even the general proportions of its parts, but simply to illustrate its principle. There are, indeed, some elements of its construction, which, for the sake of simplicity, have been altogether omitted from it. These are the trains of wheels which must be connected with each of the axes carrying the indices R, S, T to register the *complete* numbers of revolutions made by those indices, and the divided circles to which the indices point, showing such portions of the numbers N_1, N_4 , &c. as correspond to less than one complete revolution.

It will be obvious that, since the number N_2 represents (in the first adjustment of the instrument) the product of the numbers N_1 and N_3 , the divisions on the circles pointed to by the indices R and T must be greater than those of the circle pointed to by the index S, or the numbers n_1 and n_3 less than the number n_2 .

It will, moreover, be observed, that the instrument, whilst it differs from other calculating machines, and claims to be superior to them in the simplicity of its combinations, differs also, and is inferior to them in this respect, that the truth of its registrations is dependent on the mechanical accuracy of its construction.

Those elements of the machine, on the mechanical truth

and adaptation of which its accuracy depends, are,—1st, the screw, the convolutions of whose thread must be of geometrical uniformity; 2nd, the cone, whose surface must be of geometrical truth; and 3rd, the wheel, whose edge must have so intimate a contact *with*, and hold *upon*, the surface of the cone, as to partake accurately in its motion at every point which it traverses.

My experience in the use of a similar cone and wheel in a steam indicator constructed at the expense of the British Association of Science, has convinced me that the required accuracy is in this last respect attainable.

In respect to the two first-mentioned sources of error, it may be observed that there are no mechanical forms of greater simplicity than the *cone* and the *screw*, and probably none in respect to which greater truth of construction is attainable.

Every such instrument must however have its error; its *amount* in respect to this instrument may be determined by an obvious method, and it is probable that it may in every case be corrected by a corresponding *adjustment*.

XXXI. *On the use of a mixture of Spirit of Wine and Camphine, as a Light for Optical Purposes.* By JOHN GEORGE CHILDREN, Esq., F.R.S.

To Richard Taylor, Esq.

MY DEAR SIR,

Halstead Place, Feb. 13, 1847.

IF you think the following trifle worth inserting in the Philosophical Magazine, it is at your service. I have lately assisted a friend in getting up an apparatus for dissolving views, &c. on a scale too large for sufficient illumination by the best Argand lamp, and we considered condensed hydrogen gas as too dangerous an agent for a plaything; especially in private houses in the country, where much must be left in the preparation of the gases, &c. to servants unused to such duties. We set to work therefore to find a substitute that might answer our purpose; and after a few trials we obtained a tolerable light, by throwing the flame of spirit of wine on a surface of quicklime by a current of oxygen gas, something after the manner of Lieut. Drummond's original experiment*. The illumination by the flame of spirit of wine alone, however, proved to be too feeble; but by mixing a portion of camphine (spirit of turpentine) with it (which readily dissolves in alcohol)

* Philosophical Transactions, 1826, p. 330. Drummond's object and ours were somewhat different. He wanted to get an intense but small sphere of light, "adapted to the nature of a (parabolic) reflector:" we also wanted as intense a light as we could obtain, but, as we could not advantageously use a reflector, one which should likewise extend over a much larger surface.