THE optical establishment of C. P. Goerz, at Friedenau, Berlin, has just produced its 100,000th lens—a Goerz double anastigmat. To have placed upon the photographic market 100,000 anastigmat lenses in eight years (since 1893) is a noteworthy record.

M. MORENA Y ANDA publishes in the *Transactions* of the "Antonio Alzate" Society of Mexico a table showing the diurnal variability of air temperature at Tacubaya for each month of the fifteen years 1884–1898. The hours of observation are 7 a.m., 2 p.m. and 9 p.m.

DR. MAX VERWORN'S "Allgemeine Physiologie" was welcomed as a valuable work when it appeared in 1894, and its scope and character were described in these columns (vol. li., p. 529). The work has been translated into English, French, Russian and Italian, and has taken its place as a standard text-book of general physiology. The third edition has now been published by Herr Gustav Fischer, of Jena.

THE syndics of the Cambridge University Press have undertaken the publication of a work on the fauna and geography of the Maldive and Laccadive Archipelagoes. An expedition, consisting of Mr. J. Stanley Gardiner, Mr. L. A. Borradaile and Mr. C. Forster Cooper, passed eleven months in these two groups, and the work will contain the scientific results of the visit. The chief object of the expedition was to investigate the interdependence of the physical and biological factors in the formation of atolls and reefs. To this end upwards of 300 dredgings were taken, a large number of soundings were run, and every group of organisms was carefully collected. The land fauna was carefully and exhaustively collected, and, being from an undoubted oceanic area, cannot fail to be of interest. The marine collections fill in an almost unknown gap between the Red Sea and the East Indies, and are the most extensive ever obtained from any coral, oceanic area. The work will be published in eight parts, of which the first will appear in October next.

IN the last *Berichte*, Nencki and Marchlewski describe the very interesting discovery of the close chemical relationship existing between the red colouring matter of the blood and the green chlorophyll of plants. Hæmatoporphyrin a derivative of hæmoglobin, and phyllocyanin obtained from chlorophyll, both yield on reduction hæmopyrrol, which is probably an isobutyl or methyl propyl pyrrol.

IN the newly issued *Bulletin International de l'Académie des Sciences de Cracovie*, L. Bruner publishes the results of his dynamic investigations on the bromination of aromatic compounds. The dependence of the velocity of bromination on the nature and position of the substituting groups in the benzene ring has been studied, and especially the catalytic activity of the most important bromine "carriers." In respect of this capacity, aluminium, chromium, iron and thallium salts, compounds of antimony and phosphorus, and finally iodine have been investigated. It is found that the catalytic activity of the bromine "carriers" depends upon the nature of the substance which is being brominated, so that the arrangement of these bodies in a general series according to their activity is not possible. For benzene and bromobenzene the order is (1) aluminium, (2) thallium, (3) iron salts, (4) iodine, (5) antimony, (6) phosphorus halogens.

THE additions to the Zoological Society's Gardens during the past week include two Green Monkeys (*Cercopithecus callitrichus*) from West Africa, presented respectively by Mr. R. de Courcy Hickton and Mr. S. Prust; a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mrs. Mould; a Crab-eating Raccoon (*Procyon cancrivorus*) from South America, presented by Mr. B. W. Gardom; a Cuckoo (*Cuculus canorus*), British, presented by Lieut.-Colonel J. S. Benyon; an Alligator (*Alligator mississippiensis*) from North America, presented by Mr. W. Phillips; two Mocassin Snakes (*Tropidonotus fasciatus*) from North America, presented by Captain J. B. Gilliat; a Great Wallaroo (*Macropus robustus*), four Bridled Wallabies (*Onychogale frenata*) from Australia, two Parrot Finches (*Erythrura psittacea*) from New Caledonia, two Grey-headed Porphyrios (*Porphyrio poliocephalus*), two Ceylonese Terrapins (*Nicoria trijuga*) from India, five Derbian Sternotheres (*Sternothaerus derbianus*) from West Africa, two Grey Monitors (*Varanus griseus*) from North Africa, deposited; two Griffon Vultures (*Gyps fulvus*), European, received in exchange; a Wapiti Deer (*Cervus canadensis*), three Glossy Ibises (*Plegadis falcinellus*), bred in the Gardens.

## OUR ASTRONOMICAL COLUMN.

LIGHT VARIATION OF THE MINOR PLANET (345) TERCIDINA.—In the *Astronomische Nachrichten* (Bd. 156, No. 3726), Herr J. Hartmann gives an account of his investigations of the variation in brightness of this small planet, first pointed out by Prof. Max Wolf, of Heidelberg, in 1899 (*Astronomische Nachrichten*, No. 3704). Two photographs were obtained on April 20 and a third on April 22, all with the large Potsdam refractor. Reproductions are given showing the trails of the planet with reference to the neighbouring stars. The period deduced is as follows:—

| | | | |
|---|---|---|---|
| Beginning of increase | ... | 9h. 0m. | 4h. 10m. = 250m. |
| Culmination | ... ... | 10h. 14m. | |
| End of increase | ... ... | 13h. 10m. | |

In the same journal Prof. Max Wolf gives a reproduction of a photograph taken with a 6-inch Voigtlander objective on April 22, the period determined from this being about 240m., which is in close agreement with that determined from the Potsdam photographs. The value determined from the older observations on 1899 November 4 was 290 minutes.

UNITED STATES NAVAL OBSERVATORY.—The recent issue of vol. i. of the second series of *Publications* of the U.S. Naval Observatory contains the first results of work done at the institution since the removal from the old site and the remounting of the instruments at the new observatory. In this volume a new method of publication is initiated, the observations made with one instrument and extending over several years being given together instead of all observations being published annually. This first volume contains the reduced observations of the sun, moon, planets and many miscellaneous stars made with the 9-inch and 6-inch transit circles during the years 1894–1899.

## THE COMPTOMETER.[1]

IN acceding to the editor's request to contribute an article to NATURE upon this instrument, I should like at the outset to express the feeling of curiosity with which any one, familiar with the many arithmometers now so generally in use, must introduce himself to the examination of the comptometer. He will probably know before he begins that it is a mere adding machine; that whereas any arithmometer at each turn of the handle adds or subtracts, as the case may be, any figure set upon the machine, no matter how many digits within the capacity of the machine there may be, or how many times, or how fast within the capacity of the operator he may turn the handle, so that by means of the shifting result-slide multiplication and division can be performed at a rate, and without mental effort, that is a tax upon our imagination, the comptometer is a mere adding machine in which the operator acts upon one key at a time, which adds, each time he presses it, the number on its head to the corresponding digit on the register below. While, therefore, the machine is evidently well adapted for addition, which is so simple an operation that most people believe an instrument for the purpose is not worth the expense of purchasing, it would appear at first that the process of multiplying, to be explained shortly,

[1] Chicago, U.S.A.: Felt and Tarrant Manufacturing Co. Manchester: The Calculating Machine Co.

must be so cumbersome as to leave the comptometer far behind the more automatic arithmometers and so little better than head and pencil work as to be a gain of doubtful value.

When, further, he finds out that the inventor has evaded one of the principal difficulties of arithmometer design, which relates to the carrying of the tens, but which is due to the provision that this operation must occupy the second half of the turn of the handle and must, even then, be successive all down the row so as to allow of the nearly simultaneous and overlapping operations on all the digits, in the comptometer it is not possible where carryings come in to depress two keys simultaneously, for in that case the carrying will fail. On the other hand, if the keys are operated singly as many carryings as are necessary will be accomplished.

When, again, the arithmometrician, if I may so designate one familiar with the use of the arithmometer, finds that the comptometer, like the Income Tax man, can never subtract anything (it can only add, and so apparently can never divide) his despair is likely to be complete and he might well condemn the machine as a toy.

I will not go so far as to say that this exactly represented my feeling when I began to prepare this notice, for I had known the construction of the instrument for some years and was generally familiar with it. However, I did feel that, from a mechanician's point of view, it represented a retrograde step, and it was only the knowledge that the comptometer was extensively used in the United States, where appreciation of time-saving appliances is more developed than here, that made me feel that the comptometer must have advantages perhaps more than sufficient to compensate for its operative deficiencies.

The comptometer is a neat-looking instrument cased in mahogany, occupying $14\frac{1}{2} \times 7\frac{1}{2}$ inches on the table, and it is four inches deep. On the upper surface there are, in the eight-column machine, eight columns of spring-actuated number keys, nine keys to each column. The lowest key of each column, or rather the one nearest the operator, is marked in black 1, and these are called the 1 row, the next 2, and so on up to 9. All the even keys are flat and the uneven concave, so the operator knows at once, without looking, if his finger has got one row too high or too low. At the end next the operator is a row of nine number wheels, or one more than the number of columns, on one axle, seen through windows, so that only one figure on each can be read. This is called the register. The axle terminates outside on the right in a milled head, and below this there is a liberator handle. If the operator finds any figures on the result wheels that he does not want he presses the liberator handle with one finger and begins to turn the milled head. He then turns this as far as it will go, when nine 0's will appear on the number wheels. The machine is now ready to begin. If any key is pressed down the figure shown in black on that key will immediately appear on the corresponding number wheel below. If it or any other key in the same column is pressed, the figure on it will at once be added to the figure already on the number wheel. If the result is more than 9, 1 will be carried to the next number wheel to the left. If that should happen to be already 9, one will be carried on again and it will become 0. If all the figures are 9 and 1 is added to any one, then it and all to the left will immediately become 0. The action is almost instantaneous, but not quite, as each number wheel on becoming 9 leaves a trap set which it lets off on becoming 0. The trap then adds 1 to the next number wheel to the left. If this is 9 the same thing happens again, and so on across the machine as far as 9's happen to extend; so the action is really successive and the wave of motion can just be detected if it is looked for.

Any key instantly returns to its place under the action of a spring when the finger is removed. The necessary movement of the 1 keys is $\frac{1}{4}$ inch, while for the 9 keys $\frac{5}{8}$ inch is required with intermediate movement for intermediate figures. The pressure required is moderate, but more than is necessary for a typewriter. The rate of striking the keys may become, with practice, very great, so that, though numerous strokes are required in a multiplication, the result may nevertheless be found very quickly. Judging by the time that is stated to be necessary for working certain examples, a rate of six or seven strokes a second is certainly attainable, in fact, with but little practice I find this to be possible and that the machine works correctly at this rate.

The question will naturally arise here whether there is any fear of overshooting by the wheels of the register, as they are clearly set into very rapid rotation and have to be suddenly and exactly stopped. Various methods of stopping number wheels are in use in arithmometers—spring clicks, cams like the Geneva stop in clockwork, and a mere brake; the method used here is more direct and positive than any of these, for the key at the end of its depression operates a long light lever which brings a rigid stop between two pins on the number wheel of the register, locking it absolutely and ensuring its stopping in the correct position. The driving forward of the number wheels by the keys is effected by a series of long light levers, each operated by any one of the keys of one column. The 9 key is near the fulcrum end, while the 1 key is near the number wheel end and the others are in intermediate positions. A toothed arc at the end of each lever gears with a corresponding pinion on the common axis of the number wheels, and each of these pinions drives round its number wheel by a ratchet and pawl. Each number wheel in moving from 0 to 9 raises a light lever by means of a cam to its highest position, which it lets drop on completing its turn to 0 again. The lever in its descent moves on the next wheel to the left one tooth. If, therefore, the key of that wheel is being depressed at the same time, the carrying trap will not move it an extra tooth, but will merely join with its operating lever in moving it through one unit of movement, and the carrying will be lost.

To the left of each 1 key is a little push, which may be pressed with one finger when any key in that column is being depressed. This push throws the carrying trap out of gear with the next number wheel, so that no carrying can take place. This enables the operator to alter any figure in the result, or to bring it to 0 by adding to it the necessary number without, at the same time, changing any other figure to the left. They are also used in some special operations.

I have now probably written enough to enable any one interested in these machines to understand what the comptometer is like and also its mode of operation. The next thing is to explain how a machine that can only add, and only do that one figure at a time, may nevertheless be used for performing all the ordinary arithmetical operations, such as any arithmometer will perform.

Addition needs no more explanation. The speed merely depends on the rate at which an operator can read the columns of figures and get his fingers on to the right keys. A mere dab at the key such as is desirable with a typewriter is not appropriate here, as the key must be pressed right down to its stop, otherwise it may add a number less than that printed in black upon its head. To acquire the proper stroke, high speed and certainty of getting on to the right keys evidently requires practice; it would be interesting to see a really skilled operator at work.

In most arithmometers subtraction is effected (this is most generally wanted for the purpose of division) by turning the number wheels in the reverse direction, when the carrying acts in the reverse direction also. It is merely addition backwards. There is, however, a method of in effect subtracting on a machine which, like the comptometer, does not admit of backward motion. It is to add the arithmetical complement. This, for instance, has been used in some operations in Mr. Edmondson's circular machine. If you wish to subtract, say, 7, you have merely to add 3 and prevent the machine from carrying with the push. If you wish to subtract, say, 29, you have merely to add 71 and prevent the second figure from carrying. Similarly, to subtract, say, 23456789, it is merely necessary to add 76543211, each digit to be added being 9 − the one to be subtracted except the last operative digit, which must be 10 − the one to be subtracted, or 1 more than in the case of the others. If the arithmetrical complement had to be found by the operator the machine would not be of much use, but it has not. Every key has a smaller figure in red upon it, which is 9 − the black figure on the key. All that is necessary, therefore, in subtraction is to work with the red figures, bearing in mind only that the last operative figure to the right must be taken on the next key above, and that the push belonging to the last figure on the left must also be used to prevent carrying improperly.

Multiplication of any number by another of one digit is, of course, simple enough. To multiply, for instance, 37921 by 7 the series of keys corresponding to the number 37921 are each struck seven times, or else working on the 7 row the key farthest to the right is struck once, the next to the left twice, the next nine times, and so on. Either operation will produce the right answer, but the second one is preferable because, having put the finger on the last key of the seven row, there is no more occasion to look at the machine; the eyes can be kept on the paper and the series of keys struck the proper number of blows. There is no fear of sliding off on to the next row, as the change from the concave to the level keyheads would at once be felt.

If the multiplier has more than one digit the second method is still more to be followed. Take, for instance, an example illustrated in one of the pamphlets of the company, $2253 \times 84$. You do not, of course, strike the 2, 2, 5 and 3 keys 84 times or the 8 and the 4 keys 2253 times, though if you did the right answer would be found. You get on to the 4 row and strike the last key to the right three times, the next five times and the next two twice each. Then you get on to the 8 row and, starting at the last key but one to the right, you do the same again. The total number of strokes necessary may be found by adding together the digits in one factor and multiplying the sum by the number of digits in the other. In this case $12 \times 2 = 24$ strokes. That at, say, 6 strokes a second will be four seconds for the operation. Then the result has to be read and the result wiped off ready for the next. With a greater number of digits the operation is the same.

It constantly happens in extended calculations that the result upon the number wheels has to be further operated upon. If the next operation is one of addition or subtraction, the previous result is in the proper place; the same is true if it is to be divided. But if it has to be multiplied by a new number, the natural thing is to copy it down, wipe it off the machine and multiply in the usual way. This necessity, or supposed necessity, was overcome in Mr. Edmondson's machine by the ingenious method of "working off" results from the machine as distinguished from the usual way of working results on to the machine. That process is impossible in the comptometer, as it is in every other machine except Edmondson's, but instructions are given for a method of multiplying by a figure already on the register without the necessity of wiping it out, which is equally applicable to all arithmometers. It is simply to leave it there and multiply the other factor by a number which is one less than the right one. Then, as the new product by $n - 1$ is added to that by one already there, the result is what is wanted. By beginning at the left hand side instead of the right, as explained in the directions, which are abundantly clear, each new figure to be used is read from the undisturbed number wheel most to the left, so that there is no necessity to write down the intermediate result. Also, in multiplying long decimals it is best to begin at the left, as in that case a sufficient number of figures can be found on the machine, those discarded having no meaning if the figures operated upon are the results of observations and are not absolute figures.

Division can, of course, be effected if subtraction can be, for it is merely necessary to go on subtracting the divisor from the earlier digits of the quotient until what is left in those places is less than the divisor, then to shift the place one to the right and start subtracting again. The number of times the subtraction is effected at each place is the figure of the quotient at that place. This, after all, is what every arithmometer does, and the series of indices which record the number of turns of the handle in each place enable the operator to read off the quotient when he has gone as far as may be necessary.

Now in the comptometer these counting wheels, or their equivalent, are absent, and so, unlike arithmometers, it does not leave a record of a multiplication actually effected, but only of the result. If, therefore, a wrong key has been struck, except that the result is wrong there is no means of finding it out, whereas in an arithmometer it is usual to compare the setting and the record of the counting wheels with the figures given, to be sure that the actual operation given to the machine was that intended. If any one or more of the counters indicates a wrong figure it is merely necessary to put that place into operation and make so many turns of the handle with the + or − gear, or forwards or backwards, as the case may be, to make the counter read the intended number, when the result will also become right.

In the comptometer these counters are absent, and there is no kind of record in a multiplication or addition except the result of what the operator really gave to the machine. It would therefore appear that in division there can be no record of what was done, and, therefore, that it would be necessary to write down figure at a time the number of times the set of keys were struck in each place. It is just here that a pleasant surprise is met with, and a property of the method of subtracting, by adding the arithmetical complement, is available which I do not think would be foreseen by the arithmometrician in general.

The property is this. If the arithmetical complement is added to the group of digits to the left of the dividend that would be first used in ordinary division, and if the push is not put into operation to prevent the carrying, then when the addition has been effected the right number of times the digit on the result wheels which has received these carryings will itself be the same as the number of additions, and the figures to the right of it will have become less than the divisor. All the operator has to do, therefore, is to watch this wheel and count 1, 2, 3, &c., every time he strikes the proper keys; when this wheel reads the same number as his count he then looks at the figures to the right; if they are more than the divisor he goes on striking and counting until they are less. The counting here is not necessary, but it is safe. As soon as they are less the wheel receiving the carryings records the corresponding figure of the quotient, the same number, in fact, that he will have counted.

This operation is best explained by the aid of an example. Divide 365 by 52. 365 is first set on the result wheels as far to the left as possible. Then the keys carrying the red numbers 5 and 1 in the columns over 6 and 5 are struck, while the operator watches the wheel at first showing 3 and counts 1 for each time he strikes the 5 and 1 keys. These really add 48 each time.

The series of numbers indicated below will then one by one appear:—

| | | |
|---|---|---|
| | ... | 365 |
| Count 1 | ... | 413 |
| ,, 2 | ... | 461 |
| ,, 3 | ... | 509 |
| ,, 4 | ... | 557 |
| ,, 5 | ... | 605 |
| ,, 6 | ... | 653 |
| ,, 7 | ... | 701 |

The operator watches the 3 gradually getting larger while he counts. When he has counted 6 it also will read 6, but the next two figures, 5 3, are more than the divisor, so he goes on. The next count, 7, then necessarily agrees with the indication of the wheel which receives the carryings, and the operative wheels to the right show 1 as the temporary remainder, so the answer at present is 7 and 1 over. If a long decimal answer is required the figures are made to slide along the keys on the rows on which they find themselves, in this case two places at first and then one place at a time, and are pressed down, the fingers alternately and simultaneously rising and falling, while the operator counts and watches the wheel receiving the carryings, and thus each new figure of the quotient is found, the time necessary for a figure varying from two to five seconds according as it is low or high. This is the time I require after no regular practice. I expect a skilled operator would require but little more than half as much. It seems strange at first that the mere process of addition should, where necessary, lead to a long decimal quotient, but, as explained above, such a result must follow.

The gradual and irregular change of the wheel receiving the carryings until it agrees with the count, so as to give a figure of the quotient, also seems mysterious. The manufacturers do not think it necessary to explain to users why this is so, but they give the following somewhat wholesome advice. "Do not worry about why the above process brings the answer. It is simply an arbitrary rule by which any and all examples in division can be computed on the comptometer, and, once understood, is so simple that it cannot be forgotten. All there is to it is that you strike the divisor on the keys just as many times as indicated by the figure in the 'next place to the left in the register,' and then, if the remainder is larger than the divisor, strike the keys again once or more times until the remainder becomes smaller than the divisor."

There is no occasion for much worry any way, for the mystery may be explained quite easily. Let $na + r$ be the dividend and $a$ the divisor: then $n$ is the quotient and $r$ is "over." What is done by the machine is to add $1 - a$ $n$ times, counting up to $n$. When this has been done the result will be $na + r + n(1 - a) = n$, and $r$ is "over."

The operation described is quite simple, easy and quick where the divisor has two figures only, and is not inconvenient with as many as four, for then two fingers of each hand may be used and the keys struck without looking at them. When the divisor has more than four figures the process is modified in an ingenious way, but in such cases the comptometer is, in my opinion, definitely less convenient than any good arithmometer.

The comptometer is conveniently available for ordinary commercial operations, such as interest and discount, as well as for merely adding up accounts. In the ordinary machine with only decimal notation the last two columns must be retained for the pence, the next two for the shillings, leaving all the rest for the pounds. However, a special build is now promised with special shilling and pence columns, so that on this any number of money entries, taken in any order, may be very quickly added up. Nevertheless, the process of dividing by 12 or 20 on the decimal machine, for which it is necessary to strike the keys marked in black 8 and 8 or 1, as the case may be, is so rapid that the pence when added up become shillings and pence on the register in a moment, and the shillings, which must be added after the pence, become pounds and shillings in even less time, and the pounds, shillings and pence so obtained are in their proper places. The comptometer arranged for British currency would, however, be the more convenient where the adding up of accounts is mostly wanted, but it does not seem as if it would meet every case that will arise. For instance, in a large retail business the number of entries to be checked of this type, $23\frac{3}{4}$ yards at 7*s.* $9\frac{1}{4}$*d.* a yard, is so great that in one case that I know of a special branch of the office is devoted to this work alone. The cost of this branch amounts to 1000*l.* a year, and yet, partly in consequence of the amazing quickness of the clerks, but chiefly because of our hopeless non-decimal system, it is not possible with much advantage to employ mechanical means of calculation to reduce this tax upon the business. Now with a decimal money system the multiplication by 23·75 in a machine would be direct and simple enough, but I do not see how this could be *directly* effected upon the British currency comptometer. I do not see how multiplication or division by numbers of several digits can be advantageously carried out.

As a last example of the way in which ingenuity has been exercised in finding a way of making this adding machine perform other operations, I may refer to the directions for finding a square root. It is not my intention to explain this process here, but simply refer to the artifice. "The simplest way to extract square root on the comptometer is to act on the principle that in the series of odd numbers, 1, 3, 5, 7, 9, &c., the square of the number of terms always equals the sum of all the terms." On this a process of addition is devised, using the red numbers on the keys, which I find, even without much practice, is surprisingly rapid for the first three figures, but which, like the ordinary head and pencil way, becomes increasingly cumbersome with a greater number.

The comptometer is like all arithmometers in that, having found one product of two or more numbers, or having any previous result on the register, any further products of two numbers may be added to or subtracted from this, one at a time, without the necessity of writing down any intermediate result or of separately finding these products; and then, when this is done, the sums or differences of all the products may be divided by a final number. If a further division is required the comptometer differs from all arithmometers except Edmondson's in that the result is found on the same register as the previous dividend, and so it might appear that any number of divisions could be effected. This is not the case, as the quotient occasionally moves up the machine towards the left and so gets out of range, whereas in Edmondson's, as the machine is arranged in a circle, the quotients and dividends may chase each other round the machine without ever coming to a dead stop. In ordinary arithmometers the quotient gets on to the counter wheels, when nothing more can be done to it unless it is again transferred to the register.

The operation, therefore, that these machines can perform with the greatest advantage is of the form

$$\frac{ab \pm cd \pm ef \pm \ldots}{r},$$

whereas the operation that is most favourable for the use of logarithms is of the form

$$\frac{a^n\, b^m\, tab^p\, \theta \ldots}{r^q\, s^t\, tab^{p'}\, \phi \ldots},$$

*tab* representing any of the tabulated logarithmic functions. This advantage is so great that formulæ are artificially manipulated until they are finally rammed into this form and are then said to be adapted to logarithmic computation. Now the advantages of the calculating machines referred to are so great, and they are in so many ways preferable to logarithms where they can be used, that it is just as important to adapt formulæ to mechanical computation by putting them where convenient into the first of these two forms. Then, according as they can be put into one or other of these forms, machines or logarithms should be used for the purpose of computation, and no attempt should be made to use either for work specially adapted in this way for the other.

It may perhaps be worth while, by way of example, to mention that in the large number of corrections of the scale readings to bring them to circular measure that I had to make in my experiments on the constant of gravitation, I found I could calculate $\theta - \frac{1}{3}\theta^3 + \frac{1}{5}\theta^5$ in less time on an arithmometer than was required to look up the angle in the trigonometrical tables.

A few final observations are desirable bearing on the comparison of the comptometer with arithmometers.

In the first place the comptometer makes a most aggravating noise, like a typewriter through a megaphone; but other arithmometers are noisy, none, however, so bad as this machine. The only silent arithmometer is that beautiful machine invented by Prof. Selling, but this is practically unknown in this country.

To my mind the comptometer, with its single figure operations, is not so convenient as the arithmometer for reducing and computing observations in the laboratory. Its success is only rendered possible by the fact that it is a key machine, for key strokes may be so very rapid. The operating numbers on most arithmometers are set by slides and that is relatively slow, the operation, however, by the handle afterwards is vastly more rapid. Selling's arithmometer is, however, a key machine for the setting, while the turning handle is replaced by a sliding movement, one complete slide doing the work of five turns of the handle. Again, the fact that there is no record of the operating figures actually given to the comptometer seems to be, for scientific work, decidedly a drawback.

On the other hand the construction is admirable, perfectly adapted to its purpose, and, I should judge, fairly indestructible. I would on this point only make one complaint, which, however, refers to a defect in no respect essential to the machine. I refer to the difficulty of reading the numbers on the register. The figures are elegant, with a great contrast between the thick and the thin parts, and they are upon a polished reflecting wheel face. They are seen through small windows in a polished metal plate. The result is they are not as legible as they ought to be; great care has to be taken to get a suitable light, and it is useless to sit facing a window. The 3's may be confused with the 8's, the 1's with the 4's, and the 0's with the 9's. If block figures were used, and if, further, they were dead white upon a black ground, or even the reverse, and were not seen through a shining plate, this little defect, which I am surprised to see in the product of an American shop, would be remedied.

I have made no comparison between the comptometer and the slide rule because a good slide rule, such as Gravét's, cannot be approached in convenience by any mechanism where the limited accuracy of the slide rule is sufficient, nor can wheelwork machines directly find the fourth term in a proportion in which the three other terms are numbers, their squares, or roots, or trigonometrical functions, or the reciprocals of these, nor can they give logarithms at sight.

The attempts that have been made to increase the accuracy of the slide rule by increasing its length are not, in my opinion, of much success, because to gain only one more figure ten times the length, at least, is necessary. The rule must then be broken up gridiron fashion, as in General Hannyngton's,[1] Prof. Everett's and Thatcher's, or wound in a spiral as in Fuller's, or be altogether peculiar as Tower's. When an extra figure has been gained in this way the extreme handiness of the slide rule is gone, as it can no longer be carried in the pocket, it takes longer to find the place, and, as a rule, the range is limited to mere simple proportion. Where the accuracy of 1/10 per cent. given by a 26 cm. rule, or 1/20 per cent. by a half-metre Gravét rule is not sufficient, I should prefer in general five-figure logarithms or a wheel-machine to an extended slide rule. Whether the wheel-machine should be a comptometer or an arithmometer must depend upon the character of the calculations most often met with. I have attempted in my preceding remarks to give the information necessary to enable any one to judge in his own particular case.

C. V. BOYS.

[1] The Slide Rule Extended. E. and F. N. Spon, 16 Charing Cross, and Aston and Mander, Old Compton Street, Soho.