A Slide-rule for Powers of Numbers

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an E.M.F. applied for about an hour, it was then impossible to send a current through the cell even by increasing the E.M.F. to 120 volts. If such a cell was used as a rectifier, a black deposit was formed on the aluminium plate which remained constant in weight. If a direct current was sent through the cell, a white deposit was formed and the aluminium plate lost in weight. Prof. Ayrton described some experiments which seemed to show that the properties of these cells were connected with changes in the liquids of the cells.

Mr. INGLIS, in reply to Prof. Thompson, said that in the particular experiment referred to a reversal of the E.M.F. would have given a current of about 30 amperes. In the experiment mentioned by Mr. Campbell the explanation might be that when the E.M.F. was large the ions were forced into the interstices of the film and produced an effect corresponding to a diminution of electrostatic capacity. He thought that the power of an aluminium anode as a rectifier was due to increased resistance and not to back E.M.F.

XXXII. *A Slide-rule for Powers of Numbers.*

By Prof. JOHN PERRY, F.R.S.*

[Abstract.]

SOON after Mr. Lanchester showed his Radial Cursor to the Society in 1895 the Author designed this rule and gave it up as inaccurate. It was recalled to his memory by a letter from Brother Bonaventure, of Mount St. Michaels College, Dumfries, who was anxious to have tables of the logarithms of the logarithms of numbers. The Author finds his rule accurate enough for engineering calculations. He replaces the D scale of an ordinary slide-rule by a scale in which the mark m is placed at a distance representing $\log \log m$ from the mark 10. The rule exhibited enabled m^n to be calculated at one operation, where m is anything from 2 to 1000 and n is from 0.1 to 10. Again $m^{\frac{a}{n}}$ or $m^{\frac{1}{n}}$ or the logarithm of any number to any base or the delogarithization of any number to

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any base can be performed with one setting. When an answer is outside the limits 2 and 1000, two settings are needed. The log. log scale is described by Dr. Roget, Phil. Trans. 1814.

Mr. HARRISON said there could be no doubt that many who had to make calculations would avail themselves of the advantages offered by the addition of the log. log scale to the ordinary slide-rule. He would like to call attention to a further addition by which the general utility of the log. log scale was increased. It was the introduction of a log. ($-\log$) scale which increased the range of the instrument by making it possible to deal with numbers from a small fraction upwards, with the exception of an unavoidable gap near unity. It also made it possible to directly evaluate a quantity like a^{-n} . In a slide-rule, if the cursor were misplaced by a small amount the consequent error in the reading of the log. scale was, for all positions, the same fraction of the number read. On the other hand, in the log. log scale the proportionate error varied along the scale and was least at the unity end. At the particular place at which the reading is " e " or " e^{-1} " the percentage error agreed with that of the companion log. scale. At any other place where the reading was e^n the percentage error would be n times this amount. This proportionate accuracy was exactly that which was justified in dealing with experimental numbers liable to a percentage error. It was always possible to increase the degree of accuracy by splitting the numbers involved into suitable factors. Mr. Harrison also gave some account of the preparation of a ten-inch slide-rule accurate to one part in 300, which he hoped it would be possible to sell for one shilling.

Prof. EVERETT said that the slide-rule exhibited by Prof. Perry would be useful for people constantly engaged in raising numbers to strange indices. For occasional use he thought that a table of logarithms was preferable. He pointed out that a complete history of the slide-rule was given in the introduction to the original edition of Hutton's Tables. There were two distinct methods of using logarithmic scales—one due to Gunter and sensibly the same as that employed in Fuller's spiral rule, and the other that used

in ordinary slide-rules. With his own form of rule, which he found very convenient, it was possible with care to work correctly to one part in four thousand.

Mr. BOYS remarked that the slide-rule had occupied his attention for many years. The device employed by the Author for dealing with powers of numbers was perfectly well known, and the log. log scale was usually referred to as the P line. He admitted that the P line was not so much used as it should be, and hoped that the paper would serve a good purpose in drawing attention to it. He thought, however, that in working with gas- and steam-engines Lanchester's rule was eminently suitable for dealing with cases in which numbers must be raised to fractional indices. He agreed with Mr. Harrison's remarks upon the accuracy of the exponential scale, but said that they were apt to create a wrong impression. In dealing with an experimental number subject to error the accuracy obtained by the scale was sufficient, but in raising a true number to a certain power the errors introduced were large. He disagreed with Prof. Perry in his assertion that the ordinary D line was less used than the others.

Prof. GREENHILL thought it would be better to preserve the D line and replace the C line by the log. log scale. He also exhibited the form of Fuller's rule called the R.H.S.

Mr. APPLEYARD referred to the advantages of the spiral form of slide-rule, the objections to which are (1) that it is somewhat heavy, and (2) that the cylinders do not always work smoothly, so that there is delay in setting the pointers to the exact position. He suggested that the sliding parts should be arranged on geometric principles, like Lord Kelvin's slides. These principles were applicable both to cylindrical and to straight slide-rules. For the design of cables, the straight slide-rule has especially the merit of enabling $\log \frac{D}{d}$ to be read off at once.

Mr. COOPER supported Mr. Boys and Prof. Greenhill with reference to the D line, and said he thought it ought not to be abolished.

Prof. S. P. THOMPSON said an exponential rule was a very useful thing in dealing with some of the calculations

connected with alternating currents, more particularly those relating to hysteresis losses. A simple method for carrying out a lot of operations for which the slide-rule is often used, would be to commit to memory the multiplication table up to thirty-three times thirty-three.

XXXIII. *Photographs of Cross-Sections of Hollow Pencils formed by Oblique Transmission through an Annulus of a Lens.* By Miss ALICE EVERETT.*

THESE attempts were prompted by reading an interesting paper by Prof. Silvanus Thompson on "Zonal Aberration of Lenses."

The direct rays of an arc light were allowed to pass through an annulus of a simple convex lens tilted to an angle of 45° with their direction, and placed at a distance of about twice its focal length from the arc. The remainder of the lens surface was blocked out by paper gummed on to the glass. The photographic plate was placed at right angles to the course of the beam, and a series of exposures were made at gradually increasing distances from the lens. The room was darkened, the lamp being enclosed in a box with an opening at one end.

The lens used in the first series was a plano-convex of 3'' aperture, and 16'' focus, the plane side being next the light. The free annulus was $\frac{1}{10}$ of an inch broad, and 1.1 inch mean radius.

In the second series two concentric annuli were employed simultaneously, one near the margin, the other near the centre. The lens in this case was a double convex of $4\frac{1}{2}$ '' aperture, and about 1 ft. focus.

I have to thank the Authorities of the Davy-Faraday Laboratory for the facilities for making the experiments.

* Communicated by Prof. Everett, F.R.S.