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"Nec aranearum sane textus ideo melior quia ex se fila gignunt, nec noster vilior quia ex alienis libamus ut apes." JUST. LIPS. *Monit. Polit.* lib. i. cap. 1.

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[THIRD SERIES.]

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XXIX. *On the Method of producing Copies of engraved Copper-plates by Voltaic Action; on the supply of mixed Gases for* Drummond's *Light, by Electrolysis; on the Application of Electro-magnetism as a motive power in Navigation, and on Electro-magnetic Currents. By* Dr. M. H. JACOBI: *in a Letter to Mr.* Faraday.*

IT is some time since, that during my electro-magnetic labours, a fortunate accident conducted me to the discovery that we might by voltaic action make copies in relief of an engraved copper plate, and that a new inverted copy of those in relief might be obtained by the same process, so that the power was obtained of multiplying the copper copies to any extent. By this voltaic process the most delicate and even microscopic lines are reproduced, and the copies are so identical with the original that the most rigorous examination cannot find the least difference. I send you in the accompanying packet two specimens of such plates, which I hope you will accept with kindness. The one which is in relief is the copy of an original engraved with the burin; the second is the copy of that in relief, and consequently identical with the original. The third is the original plate, but covered with reduced copper. I had the intention of making a second copy, but unfortunately the plates adhere so strongly at times that it is impossible to separate them. I cannot tell the cause of this intimate union which occasionally occurs, but it appears to be the case only when the copper at the surface of which the reduction is effected is brittle, and consequently is lamellar and porous. I may dispense with describing more at large the apparatus that I make use of. It is simply a voltaic pair

* Communicated by Dr. Faraday.

à cloison where the engraved plate is used in the place of the ordinary copper plate, being plunged in the solution of sulphate of copper. I have found it necessary that a galvanometer with short wires should always make part of the circuit, so that one may judge of the force of the current and direct the action; the latter being effected by separating the electromotive plates more or less from each other or modifying the length of the conjunctive wire, or finally, diminishing more or less the conducting power of the liquid on the zinc side; but for the success of the operation it is of great importance that the solution of copper should be always perfectly saturated. The action should not be too rapid: from 50 to 60 grains of copper should be reduced on each square inch in 24 hours. The accompanying plates have been formed, one in two days, the other in one day only, and that is the reason why their state of aggregation is not so solid and compact as that of the small piece, No. 4, which has been reduced more slowly.

It is to be understood that we may reduce the sulphate of copper by making the current of a single voltaic pair pass through the solution by copper electrodes; as the anode is oxidized the cathode becomes covered with reduced copper, and the supply of concentrated solution may then be dispensed with. According to theory one might expect that exactly the same quantity of copper oxidized on one side would be reduced on the other, but I have always found a difference more or less great, so that the anode loses more than the cathode gains. The difference appears to be nearly constant, for it does not augment after a certain time, if the experiment be prolonged. A thoroughly concentrated solution of sulphate of copper is not decomposable by electrodes of the same metal, even on employing a battery of three or four pairs of plates. The needle is certainly strongly affected as soon as the circuit is completed, but the deviation visibly diminishes and very soon returns almost to zero. If the solution be diluted with water to which a few drops of sulphuric acid have been added, the current becomes very strong and constant, the decomposition goes on very regularly, and the engraved cathode becomes covered with copper of a fine pink red colour. If we replace the solution of sulphate of copper by pure water acidulated with sulphuric acid, there is a strong decomposition of water even on employing a single voltaic couple. The anode is oxidized, and hydrogen is disengaged at the cathode. At the commencement the reduction of copper does not take place; it begins as soon as the liquid acquires a blue colour, but its state of aggregation is always incoherent. I have continued this experiment for three

days, until the anode was nearly dissolved; the colour of the liquid became continually deeper, but the disengagement of hydrogen, though it diminished in quantity, did not cease. I think we may conclude from this experiment that in secondary voltaic actions there is neither that simultaneity of effect, nor that necessity of entering into combination or of being disengaged from it, which has place in primary electrolytic actions.

During my experiments many anomalies respecting these secondary actions have presented themselves which it would be too embarrassing to describe here: in fact there is here a void which it will be difficult to fill, because molecular forces which as yet we know nothing of appear to play a most important part.

With respect to the technical importance of these voltaic copies, I would observe that we may use the engraved cathode, not only of metals more negative than copper, but also of positive metals and their alloys, (excepting brass,) notwithstanding that these metals, &c. decompose the salts of copper with too much energy when alone. Thus one may make, for example, stereotypes in copper which may be multiplied as much as we please. I shall shortly have the honour to send you a bas-relief in copper, of which the original is formed of a plastic substance, which adapts itself to all the wants and caprices of art. By this process all those delicate touches are preserved which make the principal beauty of such a work, and which are usually sacrificed in the process of casting, a process which is not capable of reproducing them in all their purity. Artists should be very grateful to galvanism for having opened this new road to them.

During the last winter I frequently illuminated my saloon, which is of considerable size, by Drummond's light. The mixed gases were obtained in sufficient quantities, that is to say, at the rate of 3 or 4 cubic feet per hour, by decomposing dilute sulphuric acid (specific gravity 1·33,) between electrodes of platina by a constant battery of a particular construction. I only passed the gas through a glass tube filled with chloride of calcium, and there was neither gasometer nor any other provision for it. As soon as the voltaic current was closed the jet might be lighted, and the flame then burnt tranquilly, and of the same intensity for any length of time. The construction and manipulation of the battery, though extremely perfect, was still a little embarrassing. At present, a battery, with a decomposing apparatus which will produce from 3 to 4 cubic feet of electrolyzed gas per hour, occupies little more space than the page of paper on which I write to you (10

inches by 8 inches) and is about 9 inches in height. Behold certainly a beautiful application of the voltaic battery.

In the application of electro-magnetism to the movement of machines, the most important obstacle always has been the embarrassment and difficult manipulation of the battery. This obstacle exists no longer. During the past autumn and at a season already too advanced, I made, as you may perhaps have learned by the gazettes, the first experiments in navigation on the Neva, with a ten-oared shallop furnished with paddle-wheels, which were put into motion by an electro-magnetic machine. Although we journeyed during entire days, and usually with 10 or 12 persons on board, I was not well satisfied with this first trial, for there were so many faults of construction and want of insulation in the machines and battery which could not be repaired on the spot, that I was terribly annoyed. All these repairs and important changes being accomplished the experiments will shortly be recommenced. The experience of the past year combined with the recent improvements of the battery give as the result, that to produce the force of one horse (steam-engine estimation) it will require a battery of 20 square feet of platina distributed in a convenient manner, but *I hope* that from 8 to 10 square feet will produce the effect. If heaven preserves my health, which is a little affected by continual labours, I hope that within a year of this time, I shall have equipped an electro-magnetic vessel of from 40 to 50 horse power.

In my paper, "On the application, &c.*" I have spoken of the influence which those magneto-electric currents which you had discovered a short time before, would exert on the progress of electro-magnetic machines. They are properly the cause that the expectations which have been entertained regarding these machines have not as yet been fulfilled. But if one examines them more nearly these currents are not so disadvantageous as have been supposed. Experiments which I have made by interposing a galvanometer or a voltameter have taught me that during the action of the machine the electrolytic action of the battery is much less, and sometimes not more than half that which takes place when the machine is stopped, the current still passing by the helices which surround the bars of iron. Thus if on the one part the magneto-electric currents diminish the force of the machine, on the other the electrolytic dissolution of the zinc, which makes the greatest part of the current expense, is at the same time considerably diminished. I have not as yet succeeded in completely developing the mutual relations of the current before and during the working of the machine.

* See Taylor's Scientific Memoirs, vol. i. p. 503, and vol. ii. (Part V.) p. 1.—Edit.

I take the liberty of sending you some memoirs from the *Bulletin scientifique* of the Academy. The result of the joint memoir of myself and M. Lenz is *that the attraction of electro-magnets is as the square of the force of the current, or as the square of the electrolytic action of the battery.* It appears that this important law holds good for machines in motion; at least the experiments I have made on that point do not depart from it more than may be admitted as the error of observation or the result of accidental circumstances.

I am, &c.

St. Petersburg, June 21, 1839. M. H. Jacobi.

XXX. *On the general Solution of Algebraical Equations.* By J. W. Lubbock, *Esq.*, *F.R.S.**

LET $x^n + \ldots\ldots Cx^2 + Dx + E = 0 \ldots\ldots$ (1.) be any equation, and let

$$x = p + qy + ry^2 + sy^3 \ldots\ldots + \&c. \ldots\ldots \quad (2.)$$

y being raised to the $n-1^{th}$ power in the last term of equation (2.). Let $fy = 0$ (3.), and let α, β, γ be the roots of equation (3.). Moreover, let

$$\Sigma_1 = \alpha + \beta + \gamma \ldots \&c. \qquad \Sigma_2 = \alpha^2 + \beta^2 + \gamma^2 + \&c.$$
$$f_1 = a + b + c \ldots \&c. \qquad f_2 = a^2 + b^2 + c^2 + \&c.$$

a, b, c, &c. being the roots of equation (1.).

The equation which arises from the elimination of y between (2.) and (3.) will be, as is well known, that formed by the product (*Francœur*, vol. ii. p. 126.)

$$\{x - p - q\alpha - r\alpha^2 \ldots\ldots + \&c.\}$$

with $\{x - p - q\beta - r\beta^2 \ldots\ldots + \&c.\}$

and all similar quantities; and as this equation must be identical with equation (1.),

$$\{x - p - q\alpha - r\alpha^2 \ldots + \&c.\}$$
$$\{x - p - q\beta - r\beta^2 \ldots + \&c.\} = x^n \ldots + Cx^2 + Dx + E = 0.$$

Dividing both sides of the last equation by x^n, taking the logarithms and equating the coefficients of the same powers of x, we obtain at once the equations of condition which exist between the quantities p, q, r, &c., Σ_0, Σ_1, Σ_2, &c., and the coefficients C, D, E, &c. of the proposed equation.

Now let equation 3. be $y^n - 1 = 0$, then

$$\Sigma_0 = n, \ \Sigma_1 = 0, \ \Sigma_2 = 0, \ \&c.$$

* Communicated by the Author.