Lord Alcester assures me that there was no doubt of the breakers, otherwise it might be thought that the deceptive appearance that misled Captain Aldrich, also misled the officers of the *Pelorus*.

It thus appears probable that, as in some other cases (of which the Graham Island in the Mediterranean is perhaps best known), the cinders and ashes which formed, and still form, the summit of the volcanic mound originally thrown up, are being by wave-action gradually swept away, and will continue to be so removed until the top of the bank is reduced below the limit of such action, or, as in the case of the Graham Shoal, the solid rock is laid bare.

If so, it is another case of the preparation of a suitable foundation for coral builders by a process directly the reverse of that of building up by marine organisms on mounds that have failed to reach the surface, suggested by Mr. John Murray to be the principal method.

It remains for those who have made submarine eruptions their study to say whether a mound raised in the sea is covered with loose matter in a sufficient percentage of cases to justify this mode of coral-foundation-making being given an important place amongst others.

In the latest known cases of islands so formed, viz. Steers and Calmeyer Islands, thrown up near Krakatão in 1883, and Falcon Island, which appeared in 1885 in the Tonga Group, the surface structure was loose. The two former very shortly disappeared below the level of the sea. What is happening to the latter is not known, as it is seldom sighted; but from its volume and height (290 feet) the process of reduction, even if no compact nucleus exists above water, must be slow.

The deceptive appearance of the masses of minute organisms which floated in the vicinity of the bank is no doubt an abundant source of false reports. These clouds of matter are commoner in inclosed and calmer waters, like the Red Sea, than in open oceans, where they are so much more liable to be dispersed by the waves before they can accumulate to any size. The assistance they afforded in this instance to the searchers is remarkable, and so far as I know unique, as they are generally found in deep water. W. J. L. WHARTON.

RECENT VISIT OF NATURALISTS TO THE GALAPAGOS.

CAPTAIN J. M. DOW has placed at my disposal the subjoined short account of a visit recently paid to the Galapagos Group by the United States steamer *Albatross*, which will, I am sure, be of much interest to naturalists. P. L. SCLATER.

U.S. Commission of Fish and Fisheries,
Steamer "Albatross," Acapulco, Mexico,
April 24, 1888.

CAPTAIN J. M. DOW, *Panama*.

MY DEAR SIR,—Thinking that you might like to know something of the results of our trip to the Galapagos, I take this opportunity of writing.

Leaving Panama on the morning of March 30, we made during that day six hauls of the trawl in depths from 7 to 51 fathoms. These gave us fine results, including many species with which you are doubtless familiar. The fishes included species of *Upeneis*, *Arius*, *Polynemus*, *Aphronitia*, *Serranus*, *Selene*, *Prionotus*, *Hæmulon*, *Synodus*, *Tetrodon*, *Ophidium*, *Sciæna*, *Micropogon*, *Lophius*. We were delighted to see *Thalasophryne* and two allied species. The number of shells, Crustacea, &c., was almost innumerable. The care of so much material kept us very busy. The next day we sounded off Cape Mala, and found the depth to be 1927 fathoms. No more dredging was done until we neared the Galapagos on April 3, when we made a haul in 1379 fathoms, where the amount of material obtained was small, although it included some very good things. At the islands we made visits to eight of the principal ones, Most of our days were spent on shore, beginning early in the morning, and oftentimes bird-skinning and other work was prolonged far into the night. The islands presented a very inhospitable look along the shores, with the black lava cropping about everywhere; but in two of them (Chatham Island and Charles Island) the interior was extremely fertile and pleasant. Collecting was always difficult; but, with the co-operation of officers and men, we obtained a great quantity of material. We naturally looked to the birds first, on account of Darwin's previous work there. We have over 250 good bird-skins, besides several hundred specimens in alcohol, and a few skeletons. Of the fifty-seven species before reported from there, we obtained examples of fifty or more, and we have, in addition, several which are apparently new to science. We hope, with our material, to settle some of the curious problems of these islands.

We secured specimens of all the reptiles which have been before found there, and also hope that we have two or three new lizards. The tortoises excited great interest, and it would please you to see the many large ones which are now crawling about our decks. We expect now that we shall be able to raise them in the States.

Fishing was good at all of our anchorages, and we all had sport in catching fishes over the ship's side. We got between thirty and forty species in all, including a large brown "grouper," which is there caught and salted for the Ecuador market.

One night, while running from one island to another, we stopped and drifted for a while, and put the electric light over the side. Besides many small things, large sharks came around in great numbers. More than twenty were seen at once, and I know that the sight would have pleased you. We all regretted that you were not with us. Notwithstanding the necessity for rapid work, good-fellowship always prevailed as usual. I hope that some time you may take a trip with me on the *Albatross*, and see how we do it.

Hoping that this will not prove too long an account for you,

I remain,
Yours very sincerely,
LESLIE A. LEE.

THE BRITISH ASSOCIATION.

SECTION A—MATHEMATICAL AND PHYSICAL SCIENCE.

A Simple Hypothesis for Electro-magnetic Induction of Incomplete Circuits; with Consequent Equations of Electric Motion in Fixed Homogeneous or Heterogeneous Solid Matter, by Sir William Thomson.

(1) To avoid mathematical formulas till needed for calculation consider three cases of liquid[1] motion which for brevity I call Primary, Secondary, Tertiary, defined as follows:—Half the velocity in the Secondary agrees numerically and directionally with the magnitude and axis of the molecular spin at the corresponding point of the Primary; or (short, but complete, statement) *the half velocity in the Secondary is the spin in the Primary, and (similarly) half the velocity in the Tertiary is the spin in the Secondary.*

(2) In the Secondary and Tertiary the motion is essentially without change of density, and in each of them we naturally, therefore, take an incompressible fluid as the substance. The motion in the Primary we arbitrarily restrict by taking its fluid also as incompressible.

(3) Helmholtz first solved the problem—Given the spin in any case of liquid motion, to find the motion. His solution consists in finding the potentials of three ideal distributions of gravitational matter having densities respectively equal to $1/4\pi$ of the rectangular components of the given spin; and, regarding

[1] I use "liquid" for brevity to signify incompressible fluid.

for a moment these potentials as rectangular components of velocity in a case of liquid motion, taking the spin in this motion as the velocity in the required motion. Applying this solution to find the velocity in our Secondary from the velocity in our Tertiary, we see that the three velocity components in our Primary are the potentials of three ideal distributions of gravitational matter having their densities respectively equal to $1/4\pi$ of the three velocity components of our Tertiary. This proposition is proved in a moment,[1] in § 5 below, by expressing the velocity components of our Tertiary in terms of those of our Secondary, and those of our Secondary in terms of those of our Primary; and then eliminating the velocity components of Secondary, so as to have those of Tertiary directly in terms of those of Primary.

(4) Consider now, in a fixed solid or solids of no magnetic susceptibility, any case of electric motion in which there is no change of electrification, and therefore no incomplete electric circuit, or, which is the same, any case of electric motion in which the distribution of electric current agrees with the distribution of velocity in a case of liquid motion. Let this case, with velocity of liquid numerically equal to 4π times the electric current density, be our Tertiary. The velocity in our corresponding Secondary is then the magnetic force of the electric current system;[2] and the velocity in our Primary is what Maxwell[3] has well called the "electro-magnetic momentum at any point" of the electric current system; and the rate of decrease per unit of time, of any component of this last velocity at any point, is the corresponding component of electromotive force, due to electro-magnetic induction of the electric current system when it experiences any change. This electromotive force, combined with the electrostatic force, if there is any, constitutes the whole electromotive force at any point of the system. Hence by Ohm's law each component of electric current at any point is equal to the electric conductivity multiplied into the sum of the corresponding component of electrostatic force and the rate of decrease per unit of time of the corresponding component of velocity of liquid in our Primary.

(5) To express all this in symbols, let (u_1, v_1, w_1), (u_2, v_2, w_2), and (u_3, v_3, w_3) denote rectangular components of the velocity at time t, and point (x, y, z) of our Primary, Secondary, and Tertiary. We have (§ 1)—

$$u_2 = \frac{dw_1}{dy} - \frac{dv_1}{dz}, \quad v_2 = \frac{du_1}{dz} - \frac{dw_1}{dx}, \quad w_2 = \frac{dv_1}{dx} - \frac{du_1}{dy} \quad . \quad (1)$$

$$u_3 = \frac{dw_2}{dy} - \frac{dv_2}{dz}, \quad v_3 = \frac{du_2}{dz} - \frac{dw_2}{dx}, \quad w_3 = \frac{dv_2}{dx} - \frac{du_2}{dy} \quad . \quad (2)$$

Eliminating u_2, v_2, w_2 from (2) by (1), we find—

$$u_3 = \frac{d}{dx}\left(\frac{du_1}{dx} + \frac{dv_1}{dy} + \frac{dw_1}{dz}\right) - \left(\frac{d^2u_1}{dx^2} + \frac{d^2u_1}{dy^2} + \frac{d^2u_1}{dz^2}\right); \ \&c. \quad . \ . \ . \ . \quad (3)$$

But, by our assumption (§ 2) of incompressibility in the Primary—

$$\frac{du_1}{dx} + \frac{dv_1}{dy} + \frac{dw_1}{dz} = 0 \quad . \ . \ . \ . \ . \ . \ . \quad (4)$$

Hence (3) becomes—

$$u_3 = -\nabla^2 u_1, \quad v_3 = -\nabla^2 v_1, \quad w_3 = -\nabla^2 w_1 \quad . \ . \ . \quad (5)$$

where, as in Article xxvii. (November 1846) of my "Collected Papers" (vol. i.)—

$$\nabla^2 = \frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2} \quad . \ . \ . \ . \ . \ . \ . \quad (6)^4$$

This (5) is the promised proof of § 3.

(6) Let now u, v, w denote the components of electric current at (x, y, z) in the electric system of § 4; so that—

$$4\pi u = u_3 = -\nabla^2 u_1; \ 4\pi v = v_3 = -\nabla^2 v_1; \ 4\pi w = w_3 = -\nabla^2 w_1 \ . \ (7)$$

which, in virtue of (4), give—

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0 \quad . \ . \ . \ . \ . \ . \ . \quad (8)$$

[1] From Poisson's well-known elementary theorem, $\nabla^2 V = -4\pi\rho$.
[2] "Electrostatics and Magnetism," § 517 (Postscript) (c).
[3] "Electricity and Magnetism," §§ 585, 604.
[4] Maxwell, for quaternionic reasons, takes ∇^2 the negative of mine.

Hence the components of electromotive force due to change of current, being, (§ 5)—

$$-\frac{du_3}{dt}, \ -\frac{dv_3}{dt}, \ -\frac{dw_3}{dt},$$

are equal to—

$$4\pi\nabla^{-2}\frac{du}{dt}, \ 4\pi\nabla^{-2}\frac{dv}{dt}, \ 4\pi\nabla^{-2}\frac{dw}{dt} \quad . \ . \ . \ . \ . \ . \quad (9)$$

and therefore if Ψ denote electrostatic potential, we have, for the equations of the electric motion (§ 5)—

$$u = \frac{1}{\kappa}\left(\nabla^{-2}\frac{du}{dt} - \frac{d\Psi}{dx}\right); \quad v = \frac{1}{\kappa}\left(\nabla^{-2}\frac{dv}{dt} - \frac{d\Psi}{dy}\right);$$

$$w = \frac{1}{\kappa}\left(\nabla^{-2}\frac{dw}{dt} - \frac{d\Psi}{dz}\right) \quad . \ . \ . \ . \ . \ . \ . \quad (10)$$

where κ denotes $1/4\pi$ of the specific resistance.

(7) As Ψ is independent of t, according to § 4, we may, conveniently for a moment, put—

$$u + \frac{d\Psi}{\kappa dx} = \alpha; \quad v + \frac{d\Psi}{\kappa dy} = \beta; \quad w + \frac{d\Psi}{\kappa dz} = \gamma \ . \ . \ . \ (11)$$

and so find, as equivalents to (9)—

$$\frac{d\alpha}{dt} = \nabla^2(\kappa\alpha); \quad \frac{d\beta}{dt} = \nabla^2(\kappa\beta); \quad \frac{d\gamma}{dt} = \nabla^2(\kappa\gamma) \quad . \ . \ (12)$$

The interpretation of this elimination of Ψ may be illustrated by considering for example a finite portion of *homogeneous* solid conductor, of any shape (a long thin wire with two ends, or a short thick wire, or a solid globe, or a lump of any shape, of copper or other metal homogeneous throughout) with a constant flow of electricity maintained through it by electrodes from a voltaic battery or other source of electric energy, and with proper appliances over its whole boundary, so regulated as to keep any given constant potential at every point of the boundary; while currents are caused to circulate through the interior by varying currents in circuits exterior to it. There being no *changing electrification* by our supposition of § 4, Ψ can have no contribution from electrification within our conductor; and therefore, throughout our field—

$$\nabla^2\Psi = 0 \quad . \ . \ . \ . \ . \ . \ . \ . \ . \quad (13)$$

which, with (8) and (11), gives—

$$\frac{d\alpha}{dx} + \frac{d\beta}{dy} + \frac{d\gamma}{dz} = 0 \quad . \ . \ . \ . \ . \ . \ . \quad (14)$$

Between (12) and (14) we have four equations for three unknown quantities. These, *in the case of homogeneousness* (κ constant), are equivalent to only three, because in this case (14) follows from (12) provided (14) is satisfied initially, and proper surface condition is maintained to prevent any violation of it from supervening. But unless κ is constant throughout our field, the four equations (12) and (14) are mutually inconsistent; from which it follows that our supposition of unchangingness of electrification (§ 4) is not generally true. An interesting and important practical conclusion is, that when currents are induced in any way, in a solid composed of parts having different electric conductivities (pieces of copper and lead, for example, fixed together in metallic contact), there must in general be changing electrification over every interface between these parts. This conclusion was not at first obvious to me; but it ought to be so by anyone approaching the subject with mind undisturbed by mathematical formulas.

(8) Being thus warned off heterogeneousness until we come to consider changing electrification and incomplete circuits, let us apply (10) to an infinite homogeneous solid. As (8) holds through all space according to our supposition in § 4, and as κ is constant, (13) must now hold through all space, and therefore $\Psi = 0$, which reduces (10) to—

$$u = \frac{1}{\kappa}\nabla^{-2}\frac{du}{dt}; \quad v = \frac{1}{\kappa}\nabla^{-2}\frac{dv}{dt}; \quad w = \frac{1}{\kappa}\nabla^{-2}\frac{dw}{dt} \quad . \ . \ (15)$$

These equations express simply the known law of *electro magnetic* induction. Maxwell's equations (7) of § 783 of his "Electricity and Magnetism," become, in this case—

$$\mu\left(4\pi C + K\frac{d}{dt}\right)\frac{du}{dt} = \nabla^2 u, \ \&c. \ . \ . \ . \ . \ . \quad (15')$$

which cannot be right, I think (???), according to any conceivable hypothesis regarding electric conductivity, whether of metals, or stones, or gums, or resins, or wax, or shell-lac, or gutta-percha, or india-rubber, or glasses, or solid or liquid electrolytes; being, as seems (?) to me, vitiated for complete circuits, by the curious and ingenious, but, as seems to me, not wholly tenable, hypothesis which he introduces, in § 610, for incomplete circuits.

(9) The hypothesis which I suggest for incomplete circuits and consequently varying electrification, is simply that the components of the electromotive due to electro-magnetic induction are still $4\pi\nabla^{-2}du/dt$, &c. Thus for the equations of motion we have simply to keep equations (10) unchanged, while not imposing (8), but instead of it taking—

$$``v"^2\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)=\frac{d}{dt}\nabla^2\Psi \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where "v" denotes the number of electrostatic units in the electro-magnetic unit of electric quantity. This equation expresses that the electrification of which Ψ is the potential increases and diminishes in any place according as electricity flows more out than in, or more in than out. We thus have four equations (10) and (16) for our four unknowns, u, v, w, Ψ; and I find simple and natural solutions with nothing vague, or difficult to understand, or to believe when understood, by their application to practical problems, or to conceivable ideal problems; such as the transmission of ordinary or telephonic signals along submarine telegraph conductors and land-lines, electric oscillations in a finite insulated conductor of any form, transference of electricity through an infinite solid, &c. This, however, does not prove my hypothesis. Experiment is required for informing us as to the real electro-magnetic effects of incomplete circuits, and as Helmholtz has remarked, it is not easy to imagine any kind of experiment which could decide between different hypotheses which may occur to anyone trying to evolve out of his inner consciousness a theory of the mutual force and induction between incomplete circuits.

On the Transference of Electricity within a Homogeneous Solid Conductor, by Sir William Thomson.—Adopting the notation and formulas of my previous paper, and taking ρ to denote 4π times the electric density at time t, and place (x, y, z), we have—

$$\rho=\nabla^2\Psi=-``v"^2\int\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)dt \quad . \quad . \quad (17)$$

and, eliminating u, v, w, Ψ by this and (16) from (10), we find, on the assumption of κ constant—

$$\kappa\frac{d}{dt}\nabla^2\rho=\frac{d^2\rho}{dt^2}-``v"^2\nabla^2\rho \quad . \quad . \quad . \quad . \quad . \quad (18)$$

The settlement of boundary conditions, when a finite piece of solid conductor is the subject, involves consideration of u, v, w, and for it, therefore, equations (17) and (12) must be taken into account; but when the subject is an infinite homogeneous solid, which, for simplicity, we now suppose it to be, (18) suffices. It is interesting and helpful to remark that this agrees with the equation for the density of a viscous elastic fluid, found from Stokes's equations for sound in air with viscosity taken into account; and that the values of u, v, w, given by (17) and (10), when ρ has been determined, agree with the velocity components of the elastic fluid if the simple and natural enough supposition be made that viscous resistance acts only against change of shape, and not against change of volume without change of shape.

For a type-solution assume—

$$\rho=AE^{-qt}\cos\frac{2\pi x}{a}\cos\frac{2\pi y}{b}\cos\frac{2\pi z}{c} \quad . \quad . \quad . \quad . \quad (19)$$

and we find, by substitution in (18)—

$$q^2-\frac{\kappa}{L^2}q+\frac{``v"^2}{L^2}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where—

$$L^2=1\Big/4\pi^2\left(\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}\right) \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Hence, by solution of the quadratic (20) for q—

$$q=\frac{1}{2}\frac{\kappa}{L^2}\left\{1\pm\sqrt{\left(1-\frac{4``v"^2L^2}{\kappa^2}\right)}\right\} \quad . \quad . \quad (22)$$

[In the communication to the Section numerical illustrations of non-oscillatory and of oscillatory discharge are given.]

Five Applications of Fourier's Law of Diffusion, illustrated by a Diagram of Curves with Absolute Numerical Values, by Sir William Thomson.—(1) Motion of a viscous fluid; (2) closed electric currents within a homogeneous conductor;[1] (3) heat; (4) substances in solution; (5) electric potential in the conductor of a submarine cable when electro-magnetic inertia can be neglected.[2]

1. Fourier's now well-known analysis of what he calls the "linear motion of heat" is applicable to every case of diffusion in which the substance concerned is in the same condition at all points of any one plane parallel to a given plane. The differential equation of diffusion,[3] for the case of constant diffusivity, κ, is—

$$\frac{dv}{dt}=\kappa\frac{d^2v}{dx^2},$$

where v denotes the "*quality*" at time t and at distance x from a fixed plane of reference. This equation, stated in words, is as follows:—Rate of augmentation of the "*quality*" per unit of time is equal to the diffusivity multiplied into the rate of augmentation per unit of space of the "*quality*."

The meaning of the word "*quality*" here depends on the subject of the diffusion, which may be any one of the five cases referred to in the title above.

2. If the subject is motion of a viscous fluid, the "*quality*" is any one of three components of the velocity, relative to rectangular rectilineal co-ordinates. But in order that Fourier's diffusional law may be applicable, we must either have the motion very slow, according to a special definition of slowness; or the motion must be such that the velocity is the same for all points in the same stream-line, and would continue to be steadily so if viscosity were annulled at any instant. This condition is satisfied in laminar flow, and more generally in every case in which the stream-lines are parallel straight lines. It is also satisfied in the still more general case of stream-lines coaxal circles with velocity the same at all points at the same distance from the axis. Our present illustration, however, is confined to the case of laminar flow, to which Fourier's diffusional laws for what he calls "linear motion" (as explained above in § 1) is obviously applicable without any limitation to the greatness of the velocity in any part of the fluid considered (though with conceivably a reservation in respect to the question of stability[4]). In this case the "*quality*" is simply fluid velocity.

3. If the subject is electric current in a non-magnetic metal, with stream-lines parallel straight lines, the "*quality*" is simply current-density, that is to say, strength of current per unit of area perpendicular to the current. The perfect mathematical[5] analogy between the electric motion thus defined, and the corresponding motion of a viscous fluid defined in § 2 was accentuated by Mr. Oliver Heaviside in the *Electrician*, July 12, 1884; and in the following words in the *Philosophical Magazine* for 1886, second half-year, p. 135:—"Water in a round pipe is started from rest and set into a state of steady motion by the sudden and continued application of a steady longitudinal dragging or shearing force applied to *its boundary*. This analogue is useful because everyone is familiar with the setting of water in motion by friction on its boundary, transmitted inward by viscosity." Mr. Heaviside well calls this analogue "useful." It is, indeed, a very valuable analogy, not merely in respect to philosophical consideration of electricity, ether, and ponderable matter, but as facilitating many important estimates, particu-

[1] This subject is essentially the "electro-magnetic induction" of Henry and Faraday. It is essentially different from the "diffusion of electricity" through a solid investigated by Ohm in his celebrated paper "Die Galvanische Kette mathematisch bearbeitet," Berlin, 1827; translated in Taylor's "Scientific Memoirs," vol. ii. Part 8, "The Galvanic Circuit investigated Mathematically," by Dr. G. S. Ohm. In Ohm's work electro-magnetic induction is not taken into account, nor does any idea of an electric analogue to inertia appear. The electromotive force considered is simply that due to the difference of electrostatic potential in different parts of the circuit, unsatisfactorily, and even not accurately, explained by what, speaking in his pre-Greenian time, he called "the electroscopic force of the body," and defined or explained as "the force with which the electroscope is repelled or attracted by the body;" the electroscope being "a second movable body of invariable electric condition."

[2] This subject belongs to the Ohmian electric diffusion pure and simple, worked out by aid of Green's theory of the capacity of a Leyden jar (see "Mathematical and Physical Paper," vol. ii. Art. 73).

[3] See "Mathematical and Physical Papers," vol. ii. Art. 72.

[4] See "Stability of Fluid Motion," § 28, *Philosophical Magazine*, August 1887.

[5] It is essentially a mathematical analogy only; in the same sense as the relation between the "uniform motion of heat" and the mathematical theory of electricity, which I gave in the *Cambridge Mathematical Journal* forty-six years ago, and which now constitutes the first article of my "Electrostatics and Magnetism," is a merely mathematical analogy.

larly some relating to telephonic conductors and conductors for electric lighting on the "alternate-current" system. In a short article to be included in vol. iii. of my collected papers, which I hope will soon be published, I intend to describe a generalization, with, as will be seen, a consequently essential modification of this analogy, by which it is extended to include the mutual induction between conductors separated by air or other insulators, and currents in solids of different conductivity fixed together in contact.

4. If the subject is heat, as in Fourier's original development of the theory of diffusion, the "*quality*" is temperature.

5. If the subject is diffusion of matter, the "*quality*" is

ON $= x$

NP $= y$

$$y = \frac{2}{\sqrt{\pi}}\int_0^{2x/i} \epsilon^{-q^2} dq.$$

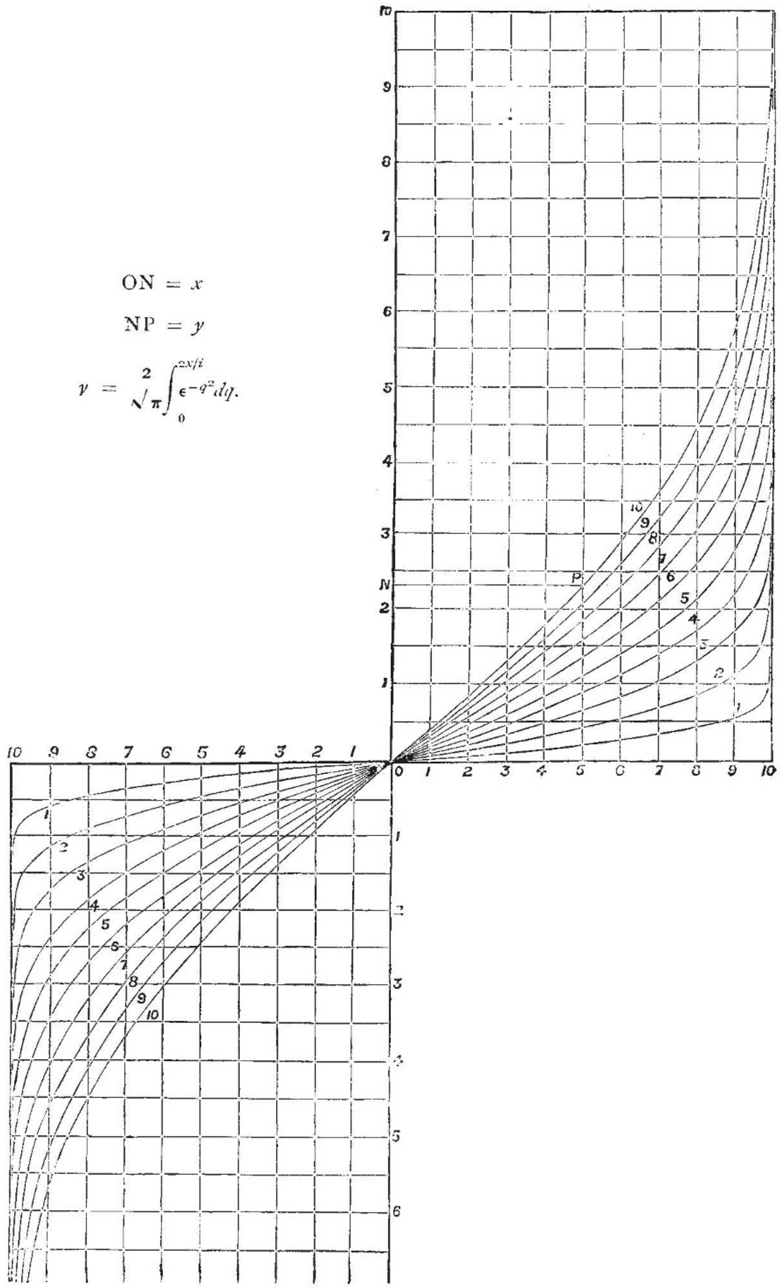

DIAGRAM SHOWING PROGRESS OF LAMINAR DIFFUSION.

density of the matter diffused, or deviation of density from some mean or standard density considered. It is to Fick, thirty-three years ago Demonstrator of Anatomy, and now Professor of Physiology in the University of Zürich, that we owe this application of Fourier's diffusional theory, so vitally important in physiological chemistry and physics, and so valuable in natural philosophy generally. When the substance through which the diffusion takes place is fluid, a very complicated but practically important subject is presented if the fluid be stirred. The exceedingly rapid progress of the diffusion produced by vigorous up-and-down-stirring, causing to be done in half a minute the diffusional work which would require years or centuries if the fluid were quiescent, is easily explained; and the explanation is illustrated by the diagram of curves, § 7 below, with the time-values given for sugar and common salt. Look at curve No. 1, and think of the corresponding curve with vertical ordinates diminished in the ratio of 1 to 40. The corresponding diffusion would take place for sugar in 11 seconds, and for salt in $3\frac{1}{2}$ seconds. The case so represented would quite correspond to a streaky distribution of brine and water or of syrup and water, in which portions of greatest and least salinity or saccharinity are within half a millimetre of one another. This is just the condition which we see, in virtue of the difference of optic refractivity produced by difference of salinity or of saccharinity, when we stir a tumbler of water with a quantity of undissolved sugar or salt on its bottom. If water be poured very gently on a quantity of sugar or salt in the bottom of a tumbler with violent stirring up guarded against by a spoon—the now almost extinct Scottish species called "toddy ladle" being the best form, or, better still, a little wooden disk which will float up with the water: and if the tumbler be left to itself undisturbed for two or three weeks, the condition at the end of 17×10^5 seconds (twenty days) for the case of sugar, or $5 \cdot 4 \times 10^5$ seconds (six days) for salt, will be that represented by No. 10 curve in the diagram.

6. If the subject be electricity in a submarine cable, the "*quality*" is electric potential at any point of the insulated conductor. It is only if the cable were a straight line that x would be (as defined above) distance from a fixed plane: but the cable need not be laid along a straight line; and the proper definition of x for the application of Fourier's formula to a submarine cable is the distance along the cable from any point of reference (one end of the cable, for example) to any point of the cable. For this case the diffusivity is equal to the conductivity of its conductor, reckoned in electrostatic units, divided by the electrostatic capacity of the conductor per unit length insulated as it is in gutta-percha, with its outer surface wet with sea-water, which, in the circumstances, is to be regarded as a perfect conductor. For demonstration of this proposition see vol. ii. Art. lxxiii. (1855) of my collected papers.

7. *Explanation of Diagram showing Progress of Laminar Diffusion.*—In each curve—

$$\frac{1}{10}NP = \frac{2}{\sqrt{\pi}}\int_0^{2x/i} dq.\epsilon^{-q^2},$$

where x denotes the number of centimetres in ON, and i the "curve-number." The curves are drawn directly from the values of the integral given in Table III., appended to De Morgan's article "On the Theory of Probabilities," "Encyclopædia Metropolitana," vol. ii. pp. 483–84.

NP denotes the "*quality*" (defined below) { at distance = ON from initial surface or interface, and at time equal in seconds to ["curve-number"]^2 divided by sixteen times the diffusivity in square centimetres per second.

Subject of Diffusion.	"*Quality*" (represented by $\frac{1}{10}NP$).
Motion of a viscous fluid ...	Ratio of the velocity at N to the constant velocity at O
Closed electric currents within a homogeneous conductor	Current-density
Heat	Ratio of temperature *minus* mean temperature to mean temperature
Substance in solution	Ratio of density *minus* mean density to mean density
Electric potential in the conductor of a submarine cable	Ratio of potential at N to constant potential at end O

EXAMPLES.

"Curve-number."	Time in Seconds.	Case of Diffusion.
1	27056	Zinc sulphate through water
1	25720	Copper sulphate through water
1	17000	Sugar through water
1	5400	Common salt through water
5	1180	Heat through wood
5	118	Laminar motion of water at 10° C.
5	30	Laminar motion of air
5	7·1	Heat through iron
5	1·31	Heat through copper
		Electric current in a homogeneous non-magnetic conductor:
10	0·0488	Copper
10	0·0040	Lead
10	0·0038	German silver
10	0·0023	Platinoid
1,000,000,000	2·15	Electric potential in the Direct U.S. Atlantic Cable

Prof. G. H. Darwin sent a paper *On the Mechanical Conditions of a Swarm of Meteorites and on Theories of Cosmogony.*—This is an abstract of a communication made to the Royal Society, in which the author proposes to apply the principles of the kinetic theory of gases to the case of a swarm of meteorites in space. In the author's theory the individual meteorites are considered to be analogous to the molecules of the gas; and thus a swarm of meteorites, in the course of conglomeration into a star, possesses mechanical properties analogous to those of a gas. Lockyer and others have expressed their conviction that the present condition of the solar system is derived from an accretion of meteorites, but the idea of fluid pressure seems necessary for the applicability of any theory like the nebular hypothesis. The author then proposes to reconcile the nebular and meteoric theories by showing that the laws of fluid pressure apply to a swarm of meteorites. The case of a globular swarm of equal-sized meteorites is considered, and then the investigation is extended to the case in which the meteorites are of various sizes; the latter extension does not affect the nature of the proof, and only slightly modifies the result. In the case of a swarm of meteorites condensing under the mutual attraction of its parts, the author shows that the larger meteorites will tend to settle towards the centre of condensation, and that consequently the mean size of the meteorites will decrease from the centre towards the outside of the swarm.

NOTES.

WE mentioned some time ago that the executors of the late Sir William Siemens, desiring to have his biography authoritatively published, had placed its preparation in the hands of Dr. William Pole, F.R.S., Honorary Secretary of the Institution of Civil Engineers, who had long been a personal friend of Sir William and his family. The work is now finished, and will be published immediately, in one volume, by Mr. Murray. It will be followed by other volumes, containing reprints of Sir William's most important scientific papers, lectures, and addresses, edited by his secretary, Mr. E. F. Bamber.

ALL who take an interest in questions relating to technical education have reason to be grateful to the Goldsmiths' Company for the way in which it has associated itself with the movement for the establishment of technical and recreative institutes in South London. By an act of splendid generosity it has secured that there shall soon be a great centre of technical instruction at New Cross. Subject to the sanction of Parliament, which will of course be readily granted, the following proposal has been accepted. Out of the surplus funds of the