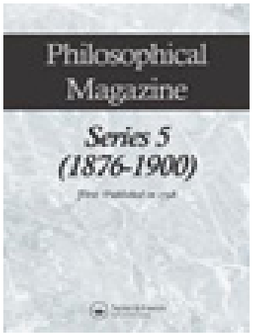

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XLV. Theoretical explanations of additional phenomena of the radiometer

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charged body instead of in the discharging wire; for, taking the model of a condenser of capacity $C\,(=(n\kappa)^{-1})$, and discharging it through a circuit of resistance ρ, the restoring force, at any instant during the discharge when the cord is displaced f and is flying back with velocity u, is

$$C^{-1}f-\rho u,$$

there being of course no time for any slip between cord and buttons. Writing this thus, with A for the total mass of all the displaced particles,

$$A\frac{d^2f}{dt^2}+\rho\frac{df}{dt}+\frac{1}{C}f=0,$$

and noticing that $f=q$, and that when $t=0$ $q=Q$ and $u=0$, we obtain at once Thomson's fundamental equation, (5) p. 395, from which all his results follow.

In this paper I have abstained from mentioning current-induction, because I have not yet read Maxwell's second volume; but the model suggests ideas as to the nature of the process concerned in producing the extra-current &c., which I expect will turn out useful.

XLV. *Theoretical Explanations of Additional Phenomena of the Radiometer.* *By* Professor Challis, *M.A., F.R.S., F.R.A.S.**

At the end of the "Theory of the Radiometer" which I proposed in the Philosophical Magazine for May 1876, I stated that I gave with reservation the explanation of the rotation of the glass globe when it is floating in water, not having then seen Mr. Crookes's communication "On the Movement of the Glass Case of a Radiometer" contained in the 'Proceedings of the Royal Society,' No. 168, p. 409. On reading that communication, I found experimental proof that the movement of the glass globe was indicative, as I had inferred from theoretical considerations, of "*friction* between the glass support and the point on which the system of vanes turns." This explanation has recently been confirmed by an experiment made by M. Jeannel (see Phil. Mag. for October 1876, p. 320), who observed that the rate of rotation was influenced by musical vibrations excited in the surrounding air, and reasonably attributes this effect to momentary suspensions of the friction between the pivot and its support caused by oscillations impressed on the instrument by the aerial vibrations.

The main purpose of the present communication is to take into theoretical consideration some additional experiments of

* Communicated by the Author.

a very remarkable character, announced by Mr. Crookes in the 'Proceedings of the Royal Society,' No. 172, p. 136. I refer chiefly to the phenomena exhibited by "a small piece of pith hanging down like a pendulum at the distance of about a millimetre from the rotating vanes of the radiometer." It was noticed that "scarcely any movement of the pendulum was produced when the rotation was very rapid; but at one particular velocity the pendulum set up a considerable movement." At the suggestion of Professor Stokes, the candle which by its light produced the rotation, was placed at the distance from the radiometer for which a revolution of an arm of the fly synchronized with a vibration of the pendulum. "In this way the pendulum was kept for some time swinging through a large arc."

To account theoretically for these facts, I have, first, to direct attention to that part of the article in the May Number where it is said (p. 396) that "the incident light thus produces an abnormal state of the atoms at and near the superficies of the vane, analogous in some degree to the state of the superficial atoms of a body *electrified* by friction." Since this was written I have seen reasons (which will presently be adduced) for concluding that the light, or heat in the radiant form, incident on the vanes has the effect, after being transmuted into heat of temperature, of so changing the relative positions of the atoms in a superficial stratum as actually to induce the electric state. According to the hydrodynamical theory of electricity which I have proposed in the Philosophical Magazine for October 1860, and in 'The Principles of Physics,' pp. 544–546, the electrified state of a solid body is solely and necessarily the result of a displacement of the atoms constituting a thin superficial stratum from their normal positions. According to the same theory such disturbance of the superficial atoms is always accompanied by an interior gradation of atomic density, in consequence of which ætherial streams are generated and maintained by the action of those ætherial vibrations to which are due, under normal circumstances, the attractive and repulsive forces treated of in my communication in the September Number. It was, in fact, argued in the "Theory of the Radiometer," given in the May Number, that the state of the vanes is such as is here stated, although they were not directly said to be electrified. I shall now assume that they are in the condition of electrified bodies, and proceed to inquire what consequences follow from this supposition relatively to the new facts it was proposed to account for.

Since the light, or heat in a radiant form, incident on the vanes is converted into heat of temperature in greater degree

at its blackened surface than at the other, the two surfaces are electrified in different degrees; and, relatively to a neutral state, one is positively electrified and the other negatively electrified. Now by an experimental law of electrical action (which is also accounted for by the hydrodynamical theory), a face of the vane, whether positively or negatively electrified, as it approaches the piece of pith will *attract* it; and the oppositely electrified face of the same vane, after passing the pith, will also attract it, supposing there is no contact between the vane and the pith. Consequently the piece of pith is drawn in opposite directions in quick succession if the rotation of the vanes be very rapid; and as impression of motion takes time, it might well happen that, under these circumstances, no perceptible motion takes place. If, however, the rotation is slow, the attraction of the vane in one direction may take effect before that in the opposite direction commences, in which case an oscillatory motion of the pith ball will be produced. Clearly the oscillations will be most steady when by reason of synchronism of the time of oscillation of the pith with the time of revolution of the vane, the attraction of a given vane acts like gravity on a pendulum. If the oscillation of the pith ball be produced, as seems to be supposed, by the intervention of the action of the vanes on the residuum of air in the globe, it is wholly inexplicable that there should be no perceptible effect when the rotation of the vane is very rapid, and might be expected to cause great disturbance of the air. The facts that no oscillation is produced by a rapid rotation, and that oscillation commences after diminishing the rate of rotation, are well accounted for by the present theory; and these explanations justify at the same time the assumption of the electric state of the vanes.

In the *Institut* of July 5, p. 213, an account is given of an experiment by M. Ducretet, according to which, by throwing ether on the glass globe to produce depression of temperature, the rotation of the vanes is first stopped, and then, by continuing the cooling, is caused to take place in the opposite direction. This result is quite in accordance with the present theory. The cooling effect of the ether, according to the law of heat-exchanges, causes the vanes to radiate less heat, or even changes the heat into cold; and as the cooling, for the same reason as the heating, is in excess at the blackened surface, the rotation might thus be stopped, and the rotating force might be made to act in the contrary direction.

The movement of the vanes is affected by two causes—the presence of a residuum of air, and the friction at the pivot above spoken of. Before exhaustion of the globe, no motion

of the vanes takes place—the reason being, according to the present theory, that no electricity can pass, air of ordinary density being a non-conductor. On producing exhaustion the rotation commences and increases up to a certain point, because rarefied air is a conductor of electricity. After a high degree of exhaustion is attained, the rate of rotation diminishes, because vacuum is a non-conductor of electricity, and an approach to that condition has a retarding effect. As the exhaustion proceeds, the effect of the friction at the pivot becomes more prominent, which, however, appears from the experimental results to be, after all, a very minute quantity. A degree of exhaustion which actually stopped the vanes was not reached. I can see no *à priori* reason why the stoppage should occur with the same degree of exhaustion as that which would prevent the passage of a galvanic spark under *particular* conditions. The vanes continued to move when the degree of exhaustion was considerably greater than that at which the spark ceased to pass under the particular conditions arranged for the comparison.

On further trial I failed to verify the statement made in the May Number, that the presence of a magnet in the neighbourhood of a radiometer affected the rate of its motion. On the contrary, I proved by more careful experiments that the streams of a magnet had *no* perceptible effect on the movement of the vanes. This result might have been anticipated from the circumstance that the electric streams of the theory traverse the vanes *transversely*, so that the addition of magnetic streams (with which, according to hydrodynamics, the electric streams may coexist) produces no variation of ætherial density at the vanes, and therefore no motive force tending to give them motion. The case would be different for a set of streams symmetrical with respect to an *axis*, inasmuch as additional streams resolved transversely to the axis would, on one side of it, coincide in direction with the original streams resolved in the same direction, and on the other side be opposed to them, so that at the axis there would be a gradation of ætherial density tending to impress motion.

I think it right to explain here that the Theory of the Radiometer I have proposed is wholly founded on those *à priori* principles (stated at the beginning of the article in the September Number) which form the basis of the theories of the different physical forces which I have for a long time been engaged in discussing and verifying, and that consequently it comes into no kind of competition with any empirical theory which the experimentalist may be able to certify by the means at his command. An established empirical theory might, how-

ever, be employed to test the truth of the *à priori* theory, because, if the latter be true, it ought to be capable of giving reasons for the experimental facts on which the empirical theory is founded. The phenomena of the radiometer have attracted my attention as being peculiarly adapted to be of service in carrying on researches as to the laws of physical force. I have, in fact, been able, by applying to them the foregoing theoretical discussion, to settle an important physical question. In my Theory of Electricity I had occasion to speak of *electricity-radiants*, but had no means of determining in what order they stood relatively to heat-radiants. The tendency of the explanations given in this communication is to prove their identity, at least, as to kind, if not in degree, with heat-radiants, and to show that, like these, they are subject to the law of exchanges. On the assumption that such is their character, I propose to conclude this communication with giving a theory of the *induction* of electricity more precise than that contained in arts. 12–16 of the "Theory of Electric Force" in the Phil. Mag. for October 1860, or that in pp. 521–531 of 'The Principles of Physics.'

This theory of electrical induction rests essentially on a certain state of the atoms at and near the surface of a body (first recognized by Poisson), according to which through an extremely small thickness the density of the atoms increases from the surface towards the interior. The fulfilment of this condition is necessary for the equilibrium of the atoms so situated. It will now be supposed that the undulations of the æther corresponding to the radiants we are concerned with can traverse substances freely without undergoing transmutation. Such undulations pertain to the electrified state of a solid body, and, in conjunction with the forces of atomic repulsion, maintain by attractive action the interior gradation of density which is a necessary condition of that state. When a body in a neutral state is brought into the neighbourhood of an electrified body, those radiants of the latter that are incident upon it pass freely through it, and consequently traverse the whole of the thin superficial stratum of varying atomic density spoken of above. Now when æther in motion, whether the motion be vibratory or steady, permeates a collection of atoms varying as to the number in a given space from point to point, there is always an increment of the velocity of the æther, and therefore a decrement of its condensation, towards the parts of greater atomic density. The variation of pressure consequent upon this variation of condensation acts upon the atoms and displaces them from their normal positions; and this, as we have already argued, suffices to induce electricity. It is, how-

ever, to be considered that this action is always towards the interior of the substance, and that the induction of electricity depends on the *difference* between the disturbances at the two positions at which the radiant cuts the surface of the body, which difference arises from the variation of the intensity of the action according to the law of the inverse square. It is evident that, although the radiants may be effective in producing motion of the atoms in the superficial stratum by reason of the variation of atomic density that subsists there, they may still be of an orderw hich, like light- and heat-radiants, produce no movement of the body as a whole.

Cambridge, October 17, 1876.

XLVI. *On certain large Crystals of Enstatite found by* W. C. Brögger *and* H. H. Reusch *at Kjorrestad near Bamle, South Norway. Memoir by* W. C. Brögger *of Christiania and* G. vom Rath *of Bonn**.

[Plate IV.]

THERE are few minerals which offer an equal interest, from the point of view of the progressive development of our knowledge of them, with the two magnesian silicates, enstatite, $MgSiO_3$, and olivine, Mg_2SiO_4. It is well known that our knowledge of the latter mineral, in proportion as it is increased, has recognized its abundance and importance. At first found almost exclusively in volcanic rocks and in small crystals, olivine has since been met with in plutonic and metamorphic rocks, the "serpentine crystals" of Snarum having been recognized as pseudomorphs after olivine. This mineral further acquires a really universal importance through its presence in meteorites.

Nearly the same may be said of enstatite. Its distribution and its importance have hitherto been less recognizable than in the case of olivine. Professor Kenngott, nearly twenty years ago, gave the name of enstatite to a mineral from Mount Zdjar in Moravia, the composition of which von Hauer determined as that of a normal silicate, $MgSiO_3$ (*Akad. Wien*, vol. xvi. p. 162, 1855). Professor Des Cloiseaux showed by means of optical researches that the crystalline system of enstatite is rhombic, and established the difference between augite and enstatite (*Bull. Soc. Geol.* vol. xxi. p. 105). Professor Rammelsberg first proved by chemical analysis that enstatite is a constituent of meteorites, the stone of Bishopsville (*Monatsber. Akad.*

* Communicated by the Crystallometric Association. Received October 9,—Read October 27, 1876.