

There is another point with regard to testing with Wheatstone's Bridge, which is not noticed in the review, but to which I may be allowed to direct attention;—that is, the position of the galvanometer. It is not indifferent in which diagonal of the bridge the battery and galvanometer are placed when the branches are unequal. In such a case the method is much more delicate when the galvanometer is placed in the diagonal joining the junction of the two largest resistances with the junction of the two smallest. As, I believe, we have in this laboratory the only Wheatstone's bridge yet constructed after Mr. Schwendler's design, by which the position of the galvanometer and battery can be altered by the shifting of four plugs, I have made a few tests which will show the advantage of this arrangement.

The diagonal joining the junction of the branches with the junction of the comparison coil and the resistance measured is called mn ; the other diagonal being pq .

Resistance measured.	No. of cells used.	Resistance of branches.	Alteration of comparison coil.	Deflection of galvanometer in diagonal	
Units.		Units.	Units.	mn	pq
90	1	$\frac{b}{a}$ 100	2	148	147
—	—	100	20	53	122
—	—	1000	200	$7\frac{1}{2}$	$34\frac{1}{2}$
		10			
		1000			

It will thus be seen that when the branch resistances are equal it is indifferent in which diagonals the galvanometer and battery are placed; but this is not the case when branch a is greater than branch b . It is hardly necessary to observe that in a practical test more than one cell would be used when the branches are unequal, in order to obtain much larger deflections, and more accurate measurements.

HERBERT MCLEOD

Royal Indian Engineering College, Cooper's Hill, January 6

The Unseen Universe—Paradoxical Philosophy

THE principle of continuity forbids us to imagine that the collocation called the atom has existed as it is from all eternity. This the authors of the "Unseen Universe" have insisted upon, and I need not go further than their title-page to remind Mr. Hallows that in like manner they do not contemplate a future eternal existence for the atom.

But this principle cannot tell us what was the exact nature of the thinkable antecedent of the present universe, nor can it tell us the exact nature of that state which will follow the disappearance of the present system. There are, however *strong scientific analogies* which lead us to believe that the thinkable antecedent of the present system was a spiritual unseen, which not only developed but which now sustains the present order.

Is it therefore necessary that I myself should in like manner help to sustain some inferior universe? I repudiate any such obligation. I am not fit for it.

Because a little boy has a father, is it logically essential that he should likewise have a son?

HERMANN STOFFKRAFT

Schloss Ehrenberg, Baden, January 11

Molecular Vibrations

IN NATURE, vol. xix. p. 158, col. 2, is the following:—

"It has been suggested that the same molecule may be capable of vibrating in different ways, and thus of yielding different spectra, just as a bell may give out different notes when struck in different ways." It is well to note that the bell as a whole gives but one sound, and the other sounds are not true harmonics, but come from parts of the bell, either before the whole is in vibration or from parts badly amalgamated, flaws in the metal, air-bubbles in pouring into the mould, lack of homogeneity, inequalities in the mould, &c.

The noises in a belfry are most discordant, whereas harmonics form a succession of consonances—octave, fifth, fourth, major and minor thirds, seventh and treble octave.

WM. CHAPPELL

The Electric Light

WHILE so many experiments are being made on lighting by the incandescence of infusible materials produced by electric currents, it is well to point out that Dr. Draper, as early as 1844, used a strip of platinum so heated to determine the facts that all solid substances become incandescent at 977° F., that light increases in refrangibility and intensity, and that the order of the colours emitted followed the true prismatic order as the temperature increases.

Dr. Draper says: "Among writers on optics it has been a desideratum to obtain an artificial light of standard brilliancy. The preceding experiments furnish an easy means of supplying that want, and give us what might be termed a 'unit lamp.' A surface of platinum of standard dimensions raised to a standard temperature by a voltaic current will always emit a constant light. A strip of that metal one inch long and $\frac{1}{16}$ th of an inch wide, connected with a lever by which its expansion might be measured, would yield at 2,000° a light suitable for most purposes. Moreover, it would be very easy to form from it a photometer by screening portions of the shining surface. An ingenious artist would have very little difficulty, by taking advantage of the movements of the lever, in making a self-acting apparatus in which the platinum should be maintained at a uniform temperature, notwithstanding any change taking place in the voltaic current." (*Vide Draper's "Scientific Memoirs,"* p. 45.)

Wimbledon, January 11

W. H. PREECE

Force and Energy¹

III.

IN consequence of energy not being a directed quantity we come at once upon an important distinction between transference of energy and transference of momentum. There may be a large force exerted, *i.e.*, a large amount of momentum rapidly transferred, without there being any accompanying transference of energy. In the distance V on the two sides of a given section of the stressed material through which the two opposite streams are flowing, there is lodged a certain amount of motion which is the same in the one portion on the one side of the section as in that on the other side. The momentum and the energy lodged in each portion are simply different functions of one and the same motion. In unit time the whole of the motion in the portion on the one side of the section is transferred into the portion on the other side, and *vice versa*. The resulting quantitative transference of the one function of the motion is double what would take place if only one, instead of two, opposite streams were flowing through the section, the reason being that this function is a directed quantity. The resulting quantitative flow of the other function of the motion is zero, because it is a function which has no direction. The rate of transference of momentum, or the force, is in this case eE , the sign being given by the sign of e . Suppose, now, one only of these streams of motion to be flowing past the section, the rate of transference of momentum being $\frac{1}{2}eE$, where e is the geometrical ratio of extension, or the strain. The rate of transference of energy remains to be calculated. The material may be either at rest or in motion. In fact whether it is to be considered at rest, or at what velocity it is to be considered moving, depends altogether upon the set of bodies relatively to which the motion is to be measured. Its relative velocity may also be either uniform or variable. The relative velocity of the centre of inertia of the material lying between two given sections will be uniform if the whole of the motion measured in any quantitative way flowing in through one of these sections is equal to that simultaneously flowing out at the other.

Suppose that before the force begins to act there is a uniform velocity, v_0 , throughout a given length. As soon as there is a uniform force, $\frac{1}{2}eE$, throughout this whole length, the flow being only in one direction, one half the particles will have at any instant the velocity, v_0 , while the other half has the velocity ($v_0 + v$), where $v = e \sqrt{\frac{E}{\mu}}$.

$V = \sqrt{\frac{E}{\mu}}$ being the velocity of stream-flow; there is in the length V lodged an amount of momentum ($V\mu v_0 + \frac{1}{2}V\mu v$) for unit section throughout that length. Of this amount $\frac{1}{2}V\mu v = \frac{1}{2}eE$ is transmitted forwards per unit of time. The mean velocity of the material is also ($v_0 + \frac{1}{2}v$).

¹ Continued from p. 219

The amount of kinetic energy lodged in this length measured relatively to the same set of bodies as v_0 relates to, is

$$\left\{ \frac{1}{2} \cdot \frac{1}{2} V \mu \cdot v_0^2 + \frac{1}{2} \cdot \frac{1}{2} V \mu \cdot (v_0 + v)^2 \right\},$$

of which there is transmitted forwards per unit of time the amount

$$\frac{1}{2} \cdot \frac{1}{2} V \mu \{ (v_0 + v)^2 - v_0^2 \} = \frac{1}{2} V \mu v \{ v_0 + \frac{1}{2} v \} = \frac{1}{2} \epsilon E \{ v_0 + \frac{1}{2} v \}.$$

This is equal to the force multiplied by the mean velocity of the material. The truth of this last proposition is quite independent of which group of bodies the velocities are measured relatively to. The energy transferred is to be measured relatively to the same group as that to which the mean velocity of the material is measured. But the expression for the rate of transference of energy consists of two parts, only one of which varies with the choice of axes of velocity-measurement. Thus the acting-force $= \frac{1}{2} \epsilon E$ = rate of transference of momentum; the mean velocity of

the material $= v_0 + \frac{1}{2} \epsilon \sqrt{\frac{E}{\mu}}$; and the rate of transference of

$$\text{energy} = \frac{1}{2} \epsilon E \left\{ v_0 + \frac{1}{2} \epsilon \sqrt{\frac{E}{\mu}} \right\} = \text{rate of doing work.}$$

The sign of the last rate indicates simply in which direction energy is flowing. The sign depends on that of the mean velocity and on that of ϵ . Here ϵ is a linear strain, and must have the sign + or -. If it is a twist it should have the sign $\sqrt{-1}$ or $-\sqrt{-1}$.

The constant part of the energy transferred—that part independent of the axis of reference—is $\frac{1}{4} \epsilon^2 E \sqrt{\frac{E}{\mu}}$. This and the

amount of the acting force cannot be altered in any way by varying the choice of axes. This result at first sight seems somewhat contradictory to the notion that energy is a thing of infinitely greater objective reality than force is. The amount of the momentum of a body's visible motion and the amount of its energy can be made just as great or as small as we please, by simply imagining one or other group of bodies to be at rest. In this way its momentum may be made to vary at will from -infinity to +infinity, while its energy may be made to vary from zero to +infinity. Etymologically the words "force," "momentum," and "energy" are mere names, but the first, force, has objective reality in the sense that it is related only to the fundamental units of mass, space, and time, and does not depend at all upon an arbitrary choice of axes; while the second and third, momentum and energy, are simply products of the imagination.

The first of these statements, viz., that respecting the physical reality of force in the sense above explained, may be objected to because of the appearance of velocities in the expression for it $\frac{1}{2} \epsilon E = \frac{1}{2} V \mu v$. But here the first velocity - V is the length of material passed through by a wave of longitudinal momentum in unit time, and it is an experimental fact that this is quite independent of the velocity of the material measured relatively to no matter what set of axes. The second velocity v is double the mean velocity of the material after the force has begun to act, measured relatively to a set of axes, relatively to which the material was at rest before the force began to act. Thus, v may be looked upon as containing in itself the definition of the axes relatively to which it is to be measured, and thus its magnitude is not at all at the disposal of our imagination.

Similarly the rate of transference of energy measured relatively to a set of axes with respect to which the material was at rest before the energy began to be transferred, is absolute in the sense that we cannot arbitrarily alter its magnitude by an exercise of the imagination.

We have in the above supposed a single stream of motion flowing continuously onwards and through the material under consideration, so that that material neither gained nor lost on the whole momentum or energy. If the portion of material considered does not pass on the whole motion it receives, but retains either a part or the whole of it, its rate of gain of energy is to be found by applying the above equations to its one or two or more surfaces, or surface layers, through which transfers of energy are going on. If it is receiving energy only through one surface and losing it through no surface, its rate of gain of energy is $\frac{1}{2} \epsilon E \{ v_0 + \frac{1}{2} v \}$, where ϵ is the strain at the receiving surface, and $(v_0 + \frac{1}{2} v)$ the velocity of that surface, measured in the proper directions. It is to be observed that new finite increments of velocity gradually spread over the whole material,

so that each small part is accelerated by fits and starts, and the whole mass is accelerated by what might be called pulsations, or, in the case of the strains being shearing ones, in a sort of wriggling fashion. The surface particles have at any instant the velocity v_0 , say. They instantaneously gain the velocity v and immediately afterwards lose it again, and experience this change a great many times for an interval during which their time-average velocity is $(v_0 + \frac{1}{2} v)$. After this interval they for another equally long interval alternate between the velocities $(v_0 + v)$ and $(v_0 + 2v)$ in such a way that their time average velocity is $(v_0 + \frac{1}{2} v)$.

The gain of energy in one unit of time is in magnitude evidently dependent on v_0 : that is, on the axes of reference arbitrarily chosen. Thus, not only can we alter the magnitude of the energy resident in a body arbitrarily by choosing different sets of axes, but, by a simple exercise of the imagination, we can set the energy possessed by any portion of the universe increasing at any arbitrarily desired time-rate. The momentum may be imagined what we like, but we cannot exercise our imagination upon its rate of transference, or force; on the other hand, both the amount at any time and the rate of transference of energy we may make what we please. This last, however, does not at all invalidate the conservation of energy as a proposition concerning the energy measured relatively to a given set of axes; because, although the time-rate of gain of energy of one portion of the collection of bodies investigated may be increased by changing from one set of axes to another, still that change creates simultaneously a correspondingly increased rate of loss of energy in another part, namely, that other part from which the energy is being transferred to the former.

It is to be observed that this change arbitrarily accomplished in the magnitude of rate of exchange of energy is only possible if a force is acting. If no force is acting, ϵ is zero, and the rate of exchange of energy is zero, whatever v_0 be.

This mathematical possibility of altering, by a change of motion-axes, the time-rate of gain of energy of any special portion of the system, seems to me to furnish the strongest conceivable argument in favour of there being existent no other kind of energy except that of motion, i.e., kinetic energy, represented algebraically by the formula $\frac{1}{2} MV^2$. If the conservation of energy is true in any sense which will include kinetic energy as part of the energy which is conserved, and if the rate of transference of energy from one part of the system to another can be altered by arbitrary changes of the velocities effected by choosing different axes, then there can be no energy that is not energy of relative velocity.

Comparing the kinds of reality to be ascribed to "force and to "energy," we see that while force has quantitative definiteness quite independent of the stand-point arbitrarily assumed by the physical imagination in viewing them, it lacks that kind of reality which some believe to be an attribute of those things only which are "conserved," because force comes into existence and goes out of it again. This kind of reality may be more or less aptly illustrated by supposing that the personality of a human being be not immortal but to come into existence either gradually or suddenly with the birth of the human being, and to go out of existence with its death. If this were the case, and if the results of the temporary existence of this human being were always to live in the subsequent history of human phenomena, then force would have very much the same sort of reality as the personality of a human being. On the other hand, the quantity of energy that exists depends on this standpoint of the imagination, but so long as this standpoint is unchanged there is no change in the amount of the energy. In other words it is "conserved." So long as the position from which it is viewed is not shifted energy can neither be created nor destroyed. To make for energy an illustration somewhat parallel to the above made for force, suppose that all mankind had agreed upon a certain unit of goodness, and that the Deity was a thing the amount of whose goodness, measured by this unit, was really dependent upon the characters of the philosophies believed in by different sets of men, or upon the characters of the men themselves, then the beneficence of the Deity would be constant so long as the philosophic stand-point from which he was considered remained the same, and would have no other kind of constancy. If this were the case then energy would have very much the same kind of reality as the Deity. Again, momentum is conserved in the same way as energy. Also, force being the rate of transference of momentum, the real existence of force implies also the real existence of motion, of which energy is

simply one of various possible algebraic function; that is, of which energy is one of various possible quantitative measures, and of which momentum is another such measure. But although the reality of force implies the reality of energy and of momentum, the absolute quantitative definiteness of force does not imply any corresponding quantitative definiteness of energy or of momentum. Now physics is distinguished from metaphysics by being essentially quantitative. It appears, then, that force is a physical reality independent of relation to axes of reference, and that energy and momentum become physical realities only when they are referred to such axes, because when not so referred, they have no quantitative definiteness. They remain, however, when not referred to axes, what may be called non-quantitative realities, and probably many people would choose to call them on that account metaphysical realities.

In conclusion I may offer one remark not strictly bearing upon the subject of this letter, which is the proper PHYSICAL use of the words force and energy, but which was suggested during an explanation of the above definition of force to a friend. There are some minds so constituted that they cannot get on at all without continually referring to metaphysical ideas. This fact should make those whose minds are not so constituted unwilling to believe, as they are very apt to do, that metaphysics is only an unreal, improper, and injurious phantasy or disease of the brain. If there are two such real sciences as metaphysics and physics, in the first place it is clearly advantageous to avoid confusion of the two as far as possible, and we may hope to be able keep them separate from the top down to the base where they rest together, or one upon the other. If there are certain words which it is very convenient to use in both these sciences and with accuracy, it is clear that they must have different definitions, *i.e.*, different meanings in the two. But it would be unfortunate if there were no correspondence between the two meanings. If the two sciences are realities they must consist in two different methods of assimilating as part of our knowledge the same facts; and the statements of the one science ought to be capable of definite translation into the language of the other. And this ought to be held in view in arranging the nomenclature of the two. Now I think that the strictly physical definition of force I have given, *viz.*, the time-rate of transference of momentum, has a true correspondence with the ordinarily accepted metaphysical idea of force as "the cause of the change of velocity in masses." Metaphysically the cause of the acceleration of momentum of the one body is the transference of momentum from the other body, and this transference is also the cause of the retardation of momentum of the other. In the physical definition quantitative accuracy is obtained by introducing the idea of the "time-rate." In a metaphysical definition quantitative accuracy is neither possible nor is it desired, the inherent difference between metaphysics and physics being that the latter is quantitative while the former is not so. The friend to whom I threw out this hint objected that I was here only going one step further back, and that the question became "what was the cause of the transference of momentum?" It was evidently he who had made the step backwards, and of course it was a metaphysical step, not objectionable in itself, but having no bearing on the matter in hand. The above question is no objection to the metaphysical statement or definition, that the cause of the acceleration of momentum is the transference of momentum. If metaphysics is fit to do anything at all it ought to be able to investigate the cause of a cause; but even if it were not able to follow the chain of causes beyond any certain point, that would not constitute any objection to the statements of causative sequence made in following along the chain to the possible limit. The metaphysical answer to the question, "What is the cause of transference of momentum?" would probably be different according to the circumstances of the transference, whether it were by impact or by gravitation, or otherwise. To show, however, that my physical definition of force has a true correspondence to the metaphysical idea, it is quite unnecessary to answer this question, it is unnecessary to go beyond the cause which is called "force" in metaphysics.

ROBERT H. SMITH

Absorption of Water by the Leaves of Plants

I FEEL sure that many of your practical readers will be pleased with the article in NATURE, vol. xix. p. 183, on the "Absorption of Water by the Leaves of Plants," as a correction of a

fallacy long held by many physiological botanists in antagonism to the experience of plain observers of nature.

In reference to the concluding remark on the statements of Prof. Calderon, the following may perhaps be interesting.

Every botanist who visits my Sewage Farm is struck with the luxuriance not only of the cultivated crops, but with that of weeds found growing, out of reach of the hoe, on hedge-banks and places whence it is impossible for their roots to reach the fertilising stream, which readily accounts for the growth of the crops.

It seems clear, therefore, that plants can absorb nitrogenous organic matter which may be wafted over their leaves by winds from a sewage-irrigated field, and I welcomed Mr. Darwin's account of insectivorous plants as a confirmation of my theory; but, after all, no one has ever doubted the power of absorbing carbon through leaves since van Helmont's celebrated experiment with the willow, and it can hardly be unnatural to credit plant-life with the power of obtaining another element of nutrition by the same channel.

ALFRED S. JONES

Havod-y-wern Farm, Wrexham

The Formation of Mountains

I HAVE deferred replying to Mr. Fisher's letter (NATURE, vol. xix. p. 172) till I had an opportunity of looking at Maxwell's "Theory of Heat;" but, having done so, I am no wiser, for I do not find the point in dispute anywhere referred to. In the "English Cyclopædia," art. "Heat," I find, however, the following statement: "If we suppose the mass of the earth to have been at any remote period at a very high temperature, the effect of the radiation of its heat through the colder surrounding space would be, to cool first the superficial strata, and successively, *though in a less degree*, the internal strata." This slower cooling of the internal parts of a heated mass seems a necessary result of the "law of exchanges," to which the supposed "more rapid cooling of the interior of the globe than the crust" seems as decidedly opposed.

Mr. Fisher's illustration certainly shows how the centre *might* cool more rapidly than the outside, if heat were not subject to laws, and could set the law of exchanges at defiance. He says: "As the people disperse they move off the more quickly the further they get from the dense mass." This would be true for heat, and exactly corresponds to the quotation given above from the "English Cyclopædia;" but it is inconsistent with Mr. Fisher's statement a little further on, that the numbers in an outer belt "may continue about the same, while those in the central crowd become fewer and fewer." The two things are contradictory; and I still fail to see how the "more rapid cooling of the interior of the earth," limited as it must be to that superficial layer within which the effects of solar heat are confined, can be held to furnish a *vera causa* for the compression and contortion of deeply seated rocks and their upheaval into mountain chains.

ALFRED R. WALLACE

Musical Notes from Outflow of Water

EVERY one is familiar with the sounds produced by water running out through a pipe from the bottom of a vessel, when the water-level has got low. The other evening I witnessed a phenomenon of this order, which has, I think, certain interesting features. Desiring to empty my cistern, and the pipes being frozen, I rigged up a gutta-percha tube siphonwise, and brought the water through it. When the orifice of the tube in the cistern got partially uncovered by the descending water-level, a series of rhythmical vibrations was generated, giving a musical note. The plane of the orifice was about vertical; but notes may be had when it is at any inclination with the horizontal water-surface. The intensity of the notes depends, I believe, partly on the difference of level of the vessels; but I cannot furnish exact data as to this, or the way the pitch is affected by various influences (width of pipe, &c.). Would some one proffer an explanation of the "mechanism" or essential character of the phenomenon? M.

Shakespeare's Colour-Names

MR. BREWIN's assertion that Shakespeare's "word was doubtless *keen*" (not *green*) in the passage ("so green, so quick, so fair an eye") in "Romeo and Juliet," iii. 5, may be put on a par with his "wonder that the correction was not made long