his initial experiments, tracings, and analyses have been conducted, lead us to hope that we have at least got an instrument which will enable us to solve the elementary problems of phonetics that have hitherto almost baffled us, although it is not suited, as yet, to fix those delicacies of utterance which were my own special object of investigation.

April 30 ALEXANDER J. ELLIS

ON repeating the experiments with the phonograph narrated by Mr. A. J. Ellis in NATURE, vol. xvii. p. 485, upon a different instrument, I have found the results of my experience to differ in several respects from his. Doubtless each instrument possesses its own individual characteristics; hence it will be the more needful to exercise caution with respect to generalisation, especially as the existing instruments are few and in the hands of few observers. Mr. Ellis has been careful to state the nature of the instrument with which his results were obtained, and the name of Mr. Stroh is a guarantee for the construction of the mechanism. The instrument with which I have been working is of homelier make, and not provided with a driving-train or governor, but simply turned by hand. The same disc—a three-inch ferrotype plate—serves as receiver and transmitter of the voice. The foil used has been, if anything, a little too thin for the purpose.

On trying the sounds *aabaa*, *aadaa*, &c., I found the consonants clearly distinguishable, except the sibilants. *Aajaa*, which is stated by Mr. Ellis to be faultily delivered by the instrument, was perfectly recognisable, and could be distinguished from *aadaa*. Neither was there any confusion between *jack* and *dack* or *tack*; but *jacques*, with the soft *j*, was sounded out by the instrument as *hāāk*. My phonograph makes the clearest possible difference between the words *bout* and *bite* when carefully spoken, the diphthongal sounds coming out beautifully as *bāāōōt* and *bīāēēt*. On reversing the motion of the handle, *tēāāāb* and *tōōāāb* were unmistakable. The double nature of some of our consonantal letters is very clearly demonstrated by this process of reversal of motion, as Messrs. Fleeming Jenkin and Ewing have already shown. To the sounds they name let me add that of *ch* in the word *cheque*, which we ordinarily pronounce *tshek*. This word gives a very peculiar sound when reversed in the machine.

The greatest difficulty—that of getting an instrument to acknowledge the sibilants—is a difficulty that all who have worked with phonograph, phonautograph, or telephone, admit. The remedy mentioned by Prof. Mayer, that of using a mouthpiece with a very small hole, has the inconvenience of diminishing materially the loudness of the articulation of the machine. I have found it better to fasten a strip of card or watchspring across the opening, edgeways, so that the voice impinges on the edge of the strip. With this device sibilants are improved; the word *scissors* becomes practicable, though "*Scots*" is still intractable. One of Mr. Stroh's instruments, which was shown at the Crystal Palace during Easter week, gave *s* and *z* fairly. In a familiar phrase the *s*es are not much missed: *Steady, boys, steady*, is given with less marked defect of speech than if uttered as *thteady, boyth, thteady*. Another point of interest that has not, I think, been yet mentioned by observers is, that the marks corresponding to the vowel sounds differ when the mouth is at different distances from the vibrating plate, but that yet there is no difference in the vowel subsequently emitted by the machine; a result which confirms the previously known independence of the vowel sound of the phase of its component partials. For some time I thought my phonograph guilty of dropping its *h*'s (though not made within the sound of Bow bells), but when that letter is spoken rapidly in a word it is recorded faithfully. *Happy land* is well heard in the instrument; and *How do you do?* is also aspirated. Curiously enough, this sentence is spoken almost as well backwards as forwards (except the aspirate), especially if spoken to the machine with a strong Scottish accent. It is remarkable how useless an instrument without a clockwork regulator is for reproducing even the simplest airs: they are simply lost in noise. Altogether the study of speech by the phonograph is most interesting, and will furnish some most valuable data to students of language and of acoustics. It is impossible to witness its performance without a tribute of acknowledgment to the extreme ingenuity and skill of its inventor, Mr. Edison.

SILVANUS P. THOMPSON

University College, Bristol, May 1

On the Use of the Virial in Thermodynamics

THE ingenious experiment and the deductions from it, described by Mr. S. Tolver Preston in NATURE, vol. xvii. p. 31, throw a flood of light on the subject of availability of heat-energy, which altogether alters the basis upon which the hitherto imperfectly expressed conditions of the use of this form of energy will be made to rest. Mr. Tolver Preston has, in fact, discovered that discriminating "sprite," or being whom Prof. Clerk-Maxwell imagined ("Theory of Heat," 1875, p. 328) singling out the fast-moving, and separating them in a space by themselves (without any expenditure of energy), from the slow-moving molecules of a gaseous mass; or what is nearly equivalent to this, he has at least shown how *some* fast-moving and *some* slow-moving particles of a mass of gas originally in equilibrium, both as to temperature and pressure, *will naturally* be so guided amongst each other, that their joint energy will become more available than it was before. But it has, perhaps, not occurred to Mr. Tolver Preston and to some of your readers, that this power or faculty of rendering heat-energy available, which mutual diffusion of heterogeneous gas-masses, either through a porous septum or in their own contiguous layers possesses, is a consequence of the general form of efficacy belonging to force, of which Prof. Clausius pointed out the existence in his important propositions on the "virial,"[1] as he has termed one of the two members, of which this kind of mechanical tendency of force is the sum. The other member of a force's "*radiality*" (as it may be termed), "with respect to a given point," is the *vis viva*[2] of the material particle upon which it acts, in a space of which the selected point is the origin. In description of this newly-discovered natural tendency of a force with respect to a given point or focus, it is enough to say that while the statical *moment* of a force, or the product of the distance of its point of application from a point or fulcrum by the resolved part of the force perpendicular to this distance tends to increase uniformly the *moment of momentum* (defined similarly with that of *force*) of the particle upon which it acts, so does the "radiancy" of a force, or the product of the distance of its point of application from a given point or "focus," *together with the vis viva* of the particle upon which it acts, tend to increase the "radiancy of momentum" of the particle described in the same way as the radiancy (or the first term of the radiality) of the force, as just defined. We may speak of the radiancies of equal and opposite reactions, or of force-pairs, in the same way that we deal in statics with the moments of couples; with similar general properties of their equilibrium, including the resolution of the total radiancy (like the impulse, the horse-power, and the moment) of a system of forces, into an internal and an external part with respect to the centre of mass of a material system upon which it acts; and there are principles of conservation of moment and of radiancy of momentum about any point, taken as centre, of all the force-pairs whose moments and radiancies balance each other on a material system. Only the system's *vis viva* referred to the centre is in the latter case the rate of change of its radiancy of momentum relatively to it. It is in the same way that the conservation of the motion of the centre of mass, and the conservation of energy, are principles of nullity or of inaction of two other forms of force-agency balancing each other on a material system (the impulse of forces, and the product of their impulse by the virtual velocity of their point of application, or their "horse-power") to which we are obliged to have special recourse to resolve the particular varieties of questions of the "transfer of energy" which occur in mechanics. But it is remarkable that the radiality of a force-pair includes the *vis viva* of its mass-couplet as one member of its mechanical efficacy, and a surprising example of an agent (evidently the agent of heat-distribution) here presents itself in which *vis viva* itself is one of the active elements of the mechanical variation or compulsion! Its total tendency in any body acted on internally only by directly reacting force-pairs is the total *vis viva*, and the sum of the virials of those force-pairs, diminished, if the body is subjected externally to a uniform pressure normal to its surface, by three times the well-known product of this latter pressure by the volume of the body (written $-3\,pv$).

[1] *Poggendorff's Annalen*, vol. cxli. (1870), p. 124. But Clausius, it should be remarked, gives the name "virial" *to half* of the quantity which I have described below as the "radiancy" of a force. An exposition of Clausius' new mechanical expression, the virial, with an explanation by its means of the process of condensation of vapours into the liquid state, was given by Prof. Clerk Maxwell in his lecture to the Chemical Society on the molecular theory of the constitution of gaseous and other bodies, in 1875. (See NATURE, vol. xi. p. 357)

[2] Using this word for *twice* the quantity usually described as a particle's "kinetic energy."