JOURNAL OF

THE TRANSACTIONS

OF

The Victoria Institute,

OR,

Philosophical Society of Great Britain.

EDITED BY THE HONORARY SECRETARY.

VOL. VII.

LONDON:
(Published for the Institute)
ROBERT HARDWICKE, 192, PICCADILLY, W.
1874.

ORDINARY MEETING, December 2, 1872.

The Rev. C. A. Row, M.A., in the Chair.

The minutes of the last meeting were read and confirmed, and the following elections announced :—

Members.—The Lord Teignmouth, Langton Hall, Northallerton ; The Right Rev. Bishop P. C. Claughton, D.D., 2, Northwick Terrace, N.W. ; The Right Hon. Stephen Cave, M.P., 35, Wilton Place ; The Venerable S. P. Boutflower, M.A. (Archdeacon of Carlisle), the Abbey, Carlisle ; The Ven. P. Jacob, M.A. (Archdeacon of Winchester), Crawley ; The Ven. C. M. Long, M.A. (Archdeacon of the East Riding of Yorkshire), Settrington ; The Ven. R. Wickham, M.A. (Archdeacon of St. Asaph), Gresford, Wrexham ; The Rev. G. Currey, D.D. (Master of the Charterhouse), Charterhouse ; The Rev. J. J. Coxhead, M.A. (Vicar of St. John's), 24, Gordon Square ; The Rev. E. B. Elliott, M.A. (Prebendary of Heytesbury), Vicar of St. Mark's, Brighton ; The Rev. J. McDougall, D.D., Darwen, Lancashire ; The Rev. R. Mitchell, Church Lane, Harper Hey, Manchester ; The Rev. J. Moorhouse, M.A. (Rector of Paddington), 57, Sussex Gardens ; The Rev. J. W. Reece, M.A. (Portman Chapel), 112, Harley Street ; T. Barker, Esq., Bramel Grange, near Stockport ; J. Colebrook, Esq., M.R.C.S., 15, Hans Place, Chelsea ; A. J. Dodson, Esq., M.I.C.E., Cambridge Park, Twickenham ; W. A. Drown, Esq. Jun., Philadelphia, U. S. ; W. Klein, Esq., 24, Belsize Park ; W. Leaf, Esq., Park Hill, Streatham ; W. Mewburn, Esq., jun., 3, Tavistock Square ; S. Vincent, Esq., Sussex Villa, King Edward's Road, Hackney.

Associates.—The Right Rev. Bishop C. J. Abraham, D.D., The Close, Lichfield ; The Right Rev. Bishop H. Cotterill, D.D., Edinburgh ; The Right Rev. Bishop F. F. McDougall, D.C.L., Godmanchester ; The Very Rev. E. M. Goulburn, D.D., Dean of Norwich, Norwich ; The Ven. P. Freeman, M.A. (Archdeacon of Exeter), Thorveolin, Collumpton ; The Ven. T. Hill, B.D. (Archdeacon of Derby), Chesterfield ; The Ven. A. Huxtable, M.A. (Archdeacon of Salisbury), Sutton Walden, Shaftesbury ; The Rev. G. Bartle, M.A., D.D., LL.D., Ph.D., Principal of Freshfield College, Formby, Liverpool ; The Rev. G. B. Blenkin, M.A. (Prebendary of Lincoln), Boston, Lincolnshire ; The Rev. T. P. Boultbee, LL D. (Principal of the London College of Divinity), St. John's Hall, Highbury ; The Rev. J. W. Buckley, M.A. (Vicar of St. Mary's), Paddington ; The Rev. G. T. Fox, M.A. (Vicar of St. Nicholas's), Durham ; The Rev. C. J. Glyn, M.A. (Rector of Witchampton, Wimborne ; The Rev. R. Gordon, 5, Red Lion Street, Wapping) ;

The Rev. J. Halley, Mem. Sydney Univ., Williamstown, Victoria, Australia; The Rev. S. Kenah, B.A., H.M.S. *Rattlesnake*, Cape of Good Hope; The Rev. Wm. Lee, D.D., Roxburgh, Kelso; The Rev. J. Martin, Sydenham Park, Sydenham; The Rev. J. Simpson, LL.D., (Vicar of Kirkby Stephen), Westmoreland; The Rev. R. J. Simpson, M.A. (Rector of St. Clement Danes), 5, Russell Square; The Rev. O. P. Vincent, M.A., 23, Devonshire Street, Portland Place; G. W. Baynham, Esq., 24, Sancheshall Street, Glasgow; J. Carr, Esq., 19, Osborne Road, Finsbury Park; T. W. Cave Thomas, Esq., Camden Road Villas; W. Forsyth, Esq., Q.C., The Firs, Mortimer, Reading; J. H. S. Graham, Esq., 1, Belgrave Terrace, Shepherd's Bush; E. Vernon Harcourt, Esq., Whitwell Hall, Yorks.; R. Heaton, Esq., The Mint, Birmingham; W. S. P. Henderson, Esq., Ryder Hall Lodge, Guildford; Professor G. S. Morris, M.A., Michigan University, Ann Arber, Michigan, U.S.; Professor H. A. Nicholson, M.D., D.Sc., M.A., Ph.D., F.R.S.E. University College, Toronto, C.W.; W. Ogle, Esq, M.D,, Friargate, Derby; B. Shaw, Esq., M.A., Barrister-at-Law, Late Fellow of Trinity College, Cambridge, 8, Cambridge Square; M. J. Stewart, Esq., M.A., Barrister-at-Law, Ardwell, Stranraer, N.B.; W. R. Warwick, Esq., M.D., Southend, Essex; T. Windeatt, Esq., Tavistock; C. Winterbottom, Esq., 16, Sloane Street.

Also the presentation of the following Works for the Library :—

"Transactions of the Royal Society," Parts 135–8. *From the Society.*

"Transactions of the Royal United Service Institution," Parts 67–8. *From the Institution.*

"Transactions of the Royal Smithsonian Institution of Washington," 1871. *From the Institution.*

"Transactions from the National Association for Promoting Social Science." *From A. C. Brebner, Esq.*

"Christian Sacerdotalism." By J. Jardine, Esq., LL.D. *From the Author.*

"The Conformation of the Material by the Spiritual." By W. C. Thomas, Esq. *From the Author.*

"The Science of Moderation." By W. C. Thomas, Esq. *Ditto.*

"The Increase of Faith." By the Rev. W. Lee, D.D. *Ditto.*

"The Days of the Son of Man." Ditto *Ditto.*

"Nineteen Years in Polynesia." By the Rev. G. Turner, LL.D. *From the Rev. S. J. Whitmee.*

"Reply to the Bishop of Salisbury." By the Venerable Archdeacon Martin. *From W. H. Ince, Esq.*

"Sermons." By the Rev. J. M'Dougall, D.D. *From the Author.*

"What Determines Molecular Action?" By I. Croll, Esq. *Ditto.*

"Zoilism." By J. Poyer. *Ditto.*

The CHAIRMAN.—It is only fair to say that this large addition to the members of the Institute is mainly due to the indefatigable exertions of the

Hon. Secretary. (Cheers.) I regret, however, to say that we have lost two members, through death, during the past week; namely, Lord Harris and Sir Donald McLeod.

The following paper was then read by the Author:—

FORCE AND ENERGY. By CHARLES BROOKE, M.A., F.R.S., V.P.V.I., &c.

THE principle of the Conservation of Energy having been by some writers misapplied to the promotion of views that lead directly to Materialism, Pantheism, or Atheism, others who rightly hold it to be one of their first and highest duties to oppose such views and to counteract their tendency, appear to have held it necessary to impugn the principle altogether, instead of assigning a limit to the scope of its legitimate application. Two essays are here specially referred to: one by the Rev. J. Moore, entitled "The Heresies of Science," published in the London *Quarterly Review* for July, 1871, in which the theories discussed are those of "Natural Selection" and "The Conservation of Energy"; the other by the Rev. J. M'Cann, D.D., entitled "Force and its Manifestations," and recently read before this society.

2. Dr. M'Cann states (§ 1) that the conservation of energy, if established, would "in Biology lead to Evolution, in Theology to Pantheism, in Philosophy to Materialism, and in Morals to Necessitarianism: this cannot be conceded as a necessary sequence, for if it be freely admitted, as the writer most heartily does, that all physical laws must ever be held to be subservient to the far higher law of an Almighty Will, he cannot be supposed, in upholding the truth of this principle, to advocate those evil tendencies, which it is admitted must ensue, if the existence of that higher law be either directly or by implication denied.

3. On the doctrine of "Evolution by Natural Selection," impugned by Mr. Moore, it would be foreign to the subject of this paper to enter at any length. That the existing order of nature might have so arisen, had it been in accordance with the will of the Creator, cannot be denied; but that any such supposed course of events has actually happened is quite another question. To the mind of the writer this doctrine presents such grave difficulties that he is unable to accept its probability, and is generally in accord with what the author of "Heresies" has written on the subject. It will only further be remarked that a belief in the progressive development of

man from any inferior animal whatever is absolutely incompatible with a belief of the existence in man of an immortal spirit; for by no conceivable process can that which is essentially not material be developed from any combination of mere material elements. It is nowhere stated of any inferior animal that "God breathed into his nostrils the breath of lives"; and it may not unreasonably be assumed that the plural noun *chayim* stands in the same relation to man's tripartite nature that *Elohim* does to the tripartite existence of the Godhead.

4. Before proceeding in an attempt to confirm the principle of the conservation of energy to the satisfaction, it may be hoped, of even the writers of the above essays, it is quite necessary to come to a distinct understanding as to the precise meaning of the terms employed, and especially those of "Force" and "Energy," since the writer has seen reason to modify in some measure the views on this subject expressed in the introduction to the last edition of his "Elements of Natural Philosophy."

5. The commonly received relative signification of the terms "Force" and "Energy" is of considerable antiquity; the terms *dynamis* and *energeia* are employed in the ethics of Aristotle, and may perhaps be best represented by the terms "potentiality" and "actuality," related as that which has the power of producing activity is to that which acts.

6. The usual definition of force is, THAT WHICH PRODUCES OR TENDS TO PRODUCE CHANGE IN THE STATE OF MATTER WITH RESPECT TO ITS REST OR MOTION. But if it be the essence of a definition, that while it comprehends the predicate or thing defined it excludes all else, then this definition is open to grave objections; it is perfectly true that force will produce or tend to produce, &c., but the inverse proposition, viz., "that which produces, or tends to produce," &c., is necessarily force, is by no means equally true, for "change in the state of matter with respect to its rest or motion" may be produced by other matter in motion (and therefore possessing energy) without the intervention of any force. This definition, therefore, appears to the writer as tending to confound "force" and "energy."

7. Force has been thus defined by our ablest recent master of experimental physics*:—"What I mean by the word force is the source or sources of all possible actions of the particles or materials of the universe." But this definition is open to much the same objection as the former, because the "source of possible actions" of matter is not *necessarily* force. Both

---

* Faraday MSS. *Croonian Lectures on Matter and Force,* by H. Bence Jones, M.D., p. 35.

these definitions, in fact, appear to comprise both force and energy.

8. The definition of force which appears to the writer least open to objection, is—THAT WHICH PRODUCES A MUTUAL ACTION BETWEEN DIFFERENT PORTIONS OR PARTICLES OF MATTER, BY WHICH THEY ARE EITHER ATTRACTED TOWARDS OR REPELLED FROM EACH OTHER. Hence, force must be essentially either attractive or repulsive in its character. By this action "energy" is imparted to the matter put in motion: hence force may be further characterized as having the power of imparting energy. But for the same reasons as those above stated, "the power of imparting energy" will not serve as a definition of force, because energy may be imparted by other matter possessing energy, without the intervention of any force.

9. Cohesive attraction may be quoted as a force acting between contiguous atoms or molecules of a body; electric and magnetic attraction and repulsion as forces acting between certain particles and masses under certain conditions only; gravitation, or weight attraction, as a force acting indiscriminately between all portions of matter: the mutual actions of masses being only the aggregate of the actions of their component particles. Heat, or more correctly speaking thermic energy, is an universal source of repulsive force acting between the particles of all kinds of matter.

10. Energy was first (as the writer believes) defined by Thomas Young to be THE POWER OF DOING WORK, and this definition does not appear to require any amendment.

11. Energy, as it exists in moving matter, is called *actual* or *kinetic:* and this kind of energy implies the existence of motion and *vice versâ,* but it is not (as it has frequently been assumed to be) identical or synonymous with motion.

12. When energy, from the circumstances of the case, remains undeveloped in matter, inactive but capable of being called into action, it is termed "potential energy." Thus the energy of chemical affinity existing between the elements of gunpowder is *potential;* but when called into action by elevation of temperature, the repulsive force existing between the particles of the highly-condensed and heated gases into which the gunpowder is resolved imparts *actual* or *kinetic energy* to the shot.

13. If a weight be raised, a certain amount of energy is expended in raising it, and so long as the body is supported, the energy expended in raising it remains potential in it; but when allowed to fall freely *in vacuo* to the level from which it was raised, the body acquires, in an active or *kinetic* form, exactly the amount of energy that was expended in raising it. Similarly

the vapour raised from the earth's surface by the heat of the sun acquires in the clouds potential energy; in again descending to the sea-level, it acquires actual energy, and may do useful work in the shape of mountain torrents, the usual motive power in mountainous districts, or mischief to the garden and greenhouse, in the solid form of hail. In a mixture of oxygen and hydrogen gases in combining proportions, the energy of chemical affinity remains potential, until by the action of heat, such as that of an electric spark, some of the gaseous atoms are brought within the sphere of their mutual attraction, when the whole unite violently with the evolution of light and heat, and form water: and the theory of conservation requires that exactly the same amount of energy that was developed in the forms of heat and light at the time of combination would be required to tear the atoms asunder again, and to place them beyond the reach of each other's attraction. Again, the energy of a pendulum is wholly potential at each extremity of its oscillation, and wholly actual at the middle or lowest point. By some writers of eminence the potential energy here described has been termed "energy of position." Practically, the term "actual" is not used, and potential is frequently used elliptically for "potential energy"; thus, we speak of the potential of an electric charge, or of a voltaic current. But it must be observed that the term potential, used substantively, has a definite meaning as employed by Laplace and Green in the analytical investigation of theories of attraction: this subject, for the purposes of the present paper, it is not necessary to consider further.

14. The theory of the conservation of energy implies that no kind of energy can be produced by human agency except at the expense of an equal amount of the same kind, or an equivalent amount of some other kind, of energy. From this it follows as a corollary, that so far as physical law is concerned, the total amount of energy in the universe must remain *unchanged*; but to assert that it is, under all circumstances, *unchangeable* is a very different matter. The creation of matter must necessarily imply the creation of energy; and those who deny the possibility of the one, must deny that of the other also; they must, in fact, deny the existence of Omnipotence. It may further be remarked, that the principle of the conservation of energy is identical with that treated in all theoretical works on dynamics as the "conservation of *vis viva*."

15. It is much to be regretted that a far greater degree of logical accuracy in the use of terms than is usually met with does not exist amongst even the ablest writers on physics, for many of the arguments adduced against physical principles lie not against

the principles themselves, but against the indefinite language in which they have from time to time been expressed. There is probably no term employed in physics that has been more misapplied, and in its misuse has led to greater confusion of ideas, than "force."

16. Mr. Justice Grove writes thus :*—"Physical science treats of matter, and what I shall term its affections, namely, Attraction, Motion, Heat, Light, Electricity, Magnetism, Chemical Affinity; when these react upon matter they constitute Forces." Attraction undoubtedly constitutes a force, but motion can mean nothing else than the act of changing the position occupied in space, and how that act can be held to constitute a force it is not easy to understand. Heat, Light, and the rest, in acting or reacting upon matter, constitute not forces, but forms or kinds of energy.

17. Professor Balfour Stewart* avoids any definition of force, but the illustrations given involve the above commonly received definition. Thus, in the case of a stone resting on the edge of a cliff that author writes :—"Whilst the stone lay on the top of the cliff the force with which the earth attracted it was counteracted by an opposite force, namely, the resistance of the support on which the stone was placed." Now, the "resistance of the support" is obviously not a *force*, but a *statical pressure*, and differs totally from its opponent, the force of gravitation, in that the one is capable, and the other incapable, of producing motion.

18. It is easy to put a case in which one force may really be counteracted by another force; as, for example, if the stone be suspended either from one end of a spring of which the other end is fixed, or by an elastic cord, then elastic force is opposed to gravitation, and both are really forces, for both are capable of producing motion.

19. Professor Ball, in a recent treatise on Experimental Mechanics, states, very dogmatically, that the true definition of a force is that which "tends to produce or destroy motion." If that be so, every obstacle to the movement of a body is a "force," which is obviously absurd. Subsequently he terms friction a "force," in strict accordance, doubtless, with the language of his definition, but not in accordance with generally received ideas on the subject.

20. Mr. Moore, in reference to the confusion of the terms employed by writers on physics, quotes from Professor Bain that "Inert matter in motion is force under every manifesta-

---

* *Correlation of Physical Forces*, fifth edition, preface, p. x.

† *Lessons in Elementary Mechanics*, second edition, 1871, pp. 7 and 8.

tion." This is so obviously an abuse of language that it needs no further comment.

21. Mr. S. Baring-Gould, in a very unsuccessful attempt to elucidate dynamical principles,* has defined force to be that which produces or resists motion; and further on we meet with confusion worse confounded, for not only "light, colour, heat, electricity," but "dimension . . . solidity, liquefaction, vaporisation," are modes or modifications of force: how "colour" and "dimension" are to "produce or resist motion" it is not easy to apprehend. An indefinite number of such misapplications of the term "force" might be further adduced, but enough has been stated to show the very loose manner in which that term has been used by writers on physical subjects.

22. The terms force and energy are frequently used indiscriminately in common parlance; "thus, it is common to speak of the *force* of the powder, and the *force* of the shot: the powder has force, but the shot only energy. Again, the terms 'force of inertia,' 'force of percussion,' 'centrifugal force,' have been frequently but erroneously employed. Inertia is simply the negation or non-existence of any disturbing energy. In cases of percussion, the energy of the striking body may be more or less imparted to the body struck, either with or without the intervention of the force of elasticity. This may be shown by means of two suspended ivory balls. If a little bit of putty be placed on the point of impact of one ball at rest, and the other be raised and allowed to impinge directly upon it, they will swing together to half the height that the one ball descended from, because the energy acquired by the descending ball is just sufficient to raise double the mass to half the height. But if the elasticity of the balls be allowed to come into play by the removal of the yielding material, then the striking ball remains at rest, and that which was struck rises very nearly to the height from which the former descended, elastic force having in this case imparted to the ball at rest nearly the remaining half of the energy of the striking ball. The instantaneous transmission of the energy of impact through a long row of glass balls in contact may be adduced as a rough illustration of the molecular transmission of energy: if the first ball of the row be struck, visible motion will be imparted to the last only. The term 'centrifugal force,' denoting the tendency of a revolving body to fly off from its orbit, will in all cases be correctly replaced by 'centrifugal energy.'"

23. In order to maintain a logical accuracy of diction in treating the subject of this paper it becomes necessary to consider

---

* *Origin and Development of Religious Belief,* Part I., chap. I.

the precise meaning of those terms which relate both to certain physical conditions of matter, and to the mental impressions which arise from them, namely; Heat, Light, and Sound. Heat was 200 years since very accurately defined by one of our ablest philosophers, as well as most precise and logical writers, John Locke, he writes:—"Heat is a very brisk agitation of the insensible parts of the object, which produces in us that sensation from whence we denominate the object hot; so what in our sensation is heat, in the object is nothing but motion." It would be perhaps still more precise to say, "heat arises from," &c., in place of "heat is," &c., because the latter part of the definition states heat to be not the motion, but the perception of it.

24. Precisely the same definition will serve equally well for Light, if "light" be substituted for "heat, and "luminous" for "hot." It would then read thus:—Light is a very brisk agitation of the insensible parts of the object, which produces in us that sensation from whence we denominate the object luminous; so that what in our sensation is light, in the object is nothing but motion.

25. A very similar definition may be assigned to Sound, which has, nevertheless, been declared by the authors of both essays to be incapable of definition, thus:—*Sound is the impression on the proper organs of hearing produced by certain vibratory movements of matter;* "so that what in our sensation is sound, in the object is nothing but motion."

26. Sonorous vibrations may enter the ear of the deaf man, and it may be that the tympanum may respond to them, while the organic lesion happens to be more deeply seated, but he will tell you there is no sound; similarly, vibrations of another kind may enter the eye, and paint their perfect picture on the retina, but if the optic nerve have lost its function, the blind one will tell you there is to him no light.

27. The correctness of Locke's definition of heat has been remarkably confirmed by a bold and hazardous experiment performed on himself by Professor Tyndall, which he most judiciously recommends *not* to be repeated. If a concave reflector be suitably placed behind the luminous carbon-points of an electric lamp, the rays of light and heat will be concentrated in a powerful focus at a distance of a few inches in front of the lamp. If the eye were so placed that this focus of rays would fall on the retina, there can be little doubt that actual disorganisation of that structure would ensue. By placing a vessel formed of parallel plates of glass containing a sufficiently strong solution of iodine in carbonic bisulphide between the lamp and the focus, the whole of the luminous rays may be intercepted,

while nearly all the thermic rays are transmitted, constituting what has been called "dark" or "invisible" heat. That concentrated, though invisible, heat really exists at the focal point may be readily shown by employing it in lighting a match or a cigar, and if a thin sheet of platinum coated with a deposit of the same metal in a state of minute subdivision, in order to render it more absorbent of heat, be so placed as to receive the focal rays, it will immediately become white hot, and a visible image of the carbon points will be produced on its surface. Professor Tyndall inferred that as these rays were invisible, that is, that they were incapable of affecting the retina of the eye, they would produce no effect on that structure, however concentrated; he therefore so placed his own eye that the focus might fall on his retina, and perceived no effect whatever; the vibratory motion was there in all its intensity, but there was no *heat,* because the appropriate means of perception were absent. But on the contrary if the skin of the hand were placed at this focal point, it would speedily become charred, thus showing its power of being affected by heat.

28. The term "invisible light" has been made use of; but in reference to the definition given above, it evidently involves a contradiction; the term has been applied to those rays which are incapable of affecting the eye, but are at the same time capable of being changed into other rays which have that power, by the action of certain substances on which they may fall.

29. Light and heat have frequently been illogically designated simply as "modes of motion" by able physicists; this appears to have led many (the authors of the above-mentioned essays not excepted) into a hopeless confusion of the terms force, energy, and motion. Doubtless in common parlance the terms light and heat will continue to be applied not to the sensuous impressions produced, but to the agent producing them; but it must be borne in mind that they are forms or kinds of energy, and not "modes of motion."

30. It may be remarked that light and heat, electricity and magnetism, which are all now more or less generally recognized as forms of energy, have all been assumed to be *material,* but *imponderable.* The Newtonian or corpuscular theory of light sufficed to explain ordinary optical phenomena until the discovery of diffraction and interference, when a very forced supplementary hypothesis became necessary—namely, that the molecules of light were egg or spindle-shaped, and made perpetual somersaults during their onward progress, rebounding or being reflected from the surface of a medium, if they encounter it sideways, but penetrating and being refracted, if they meet the surface endwise: but even this is insufficient to

account for the phenomena of polarisation. But all observed phenomena of light are in perfect harmony with the undulatory theory, as now commonly accepted; and not only does this theory fit all previous observations, but the appearance that will be presented to the eye, when a ray of light is transmitted through any hitherto untried arrangement of transparent media, may safely be predicted by analysis, as in the remarkable case of Airy's spirals, seen when a polarised ray is successively transmitted through two plates cut from a right and a left-handed quartz crystal. Caloric was once assumed to be the matter or substance of heat; and the observed radiation of cold induced Black to ascribe to cold an independent material existence; but the observed phenomena are completely explicable on the "theory of exchanges," which means that every body radiates *its own* temperature, whether high or low, and that every surrounding body absorbs the radiations; consequently, the radiations of a cold body will lower the heat of a warmer body in its vicinity, just as a cistern with two pipes of unequal bore will, if fed by the larger and emptied by the smaller, become gradually fuller, while if fed by the smaller and emptied by the larger, its contents will be diminished: the parallel, in absorbed and emitted radiations, is obvious.

31. Again, it was formerly taught that there were two electric "fluids"—the "vitreous" and "resinous"; but these were subsequently merged into one, and the positive and negative aspects of electricity were assumed to be differences in *quantity* only, and not in *kind*, positively electrified bodies being in excess, and those negatively electrified, in defect of the normal quantity. Moreover, magnetic properties were supposed to be vested in two "fluids"—the "austral" and "boreal"—possessing mutually attractive and self-repulsive properties. But all these theories are more than probably alike groundless; they are, moreover, utterly inconsistent with the perpetually recurring interchanges of the various presumed forms of energy; for it is impossible to conceive one kind of matter to be converted into another kind, or matter to be converted into mere motion, and *vice versâ*.

32. In the vibratory motions of the atmosphere and other bodies, which convey to the ear the impression of sound, the vibrations are demonstrably longitudinal; that is, the vibratory motion of each particle is in the direction in which the wave is travelling, as in the wave the wind produces in a field of corn: in the vibrations of light and heat, the phenomena of polarisation require that they must be transverse, that is, the vibration of each particle must be in a plane perpendicular to the direction of the wave, as in the ripples on the surface of still water.

33. If electricity, and therefore magnetism, consist also of vibratory motion (an assumption which the obvious interchange of the former with other forms of energy necessitates), then the probable form of electric and magnetic wave-motion becomes an interesting subject of inquiry. It must be observed that both electricity and magnetism possess a dual character not common to other forms of energy; there is *positive* and *negative* electricity, *austral* and *boreal* magnetism, but there is no analogous *a* and *b* condition in light or heat. Now, is there any conceivable kind of wave-motion that would present this duality of character? Undoubtedly there is—namely, a helical wave, in which the motion of each disturbed particle is in a circle, the plane of which is perpendicular to the direction of the wave. If a helix be called *positive* when it turns from left to right, and *negative* when it turns the contrary way, from right to left, then a progressive motion in the same helix will appear positive or negative, according to the end at which it is viewed; also, opposite motions in the same helix may be conceived to interfere, and to give rise to repulsion, while opposite motions in opposite helices would progress without interference—like two series of waves on the surface of the water crossing each other—and this may, perhaps, be the source of electrical attraction.

34. It has recently been stated that no physicist of note has suggested the nature of the motion which constitutes electricity and magnetism. That may be so, but it is a fact that some years have elapsed since the above suggestion was first made by the writer: it has also been made by some others.

35. The intimate relation—it may be said the identity—of electricity and magnetism may be shown by means of De la Rive's floating battery, consisting of a small voltaic element, floating in a vessel of water, the electrodes of which are connected with the ends of a small cylindrical coil of insulated copper wire resting horizontally on the element. This coil manifests all the properties of a floating magnetic needle, taking its position in the magnetic meridian, and one end being attracted, and the other repelled, by either of the poles of a bar-magnet. Since magnetic effects are ordinarily exhibited by steel or iron, it might be supposed by some that this metal is essential to the development of magnetic energy; it is, however, merely the ordinary and most susceptible vehicle of magnetism. Since magnetic energy is manifested in a direction at right angles to the electric current that produces it, the dynamic difficulty of resolving one helical wave into another at right angles to the former must not be lost sight of, but it is probably not insuperable. There is, however, some valid

experimental confirmation of the helical character of the magnetic wave. The energy or, as it has sometimes been erroneously termed, the inertia of rotation—*i.e.*, the resistance which a rotating body offers to any change in the direction of its axis of rotation—is well exemplified by the gyrascope, and a more familiar illustration is found in the undeviating path of the rifle-ball. Now, if a mass of copper be suspended by a string between the poles of a powerful electro-magnet, and be put in rapid rotation by twisting the string, the instant that the magnet is excited, the rotation is arrested; and if the mass be now forcibly rotated, so much heat is developed by molecular friction, that fusible metal contained in a copper tube similarly placed may be actually melted and poured out. This arrest of the motion of the rotating mass would be a necessary dynamical sequence of the helical wave-motion assumed to constitute magnetic energy; for in that case each disturbed molecule would be describing a circular orbit in a plane at right angles to the lines of magnetic energy, and would by its own energy resist any displacement of its axis of revolution; and this view may be further confirmed by another experiment. A ball of copper with a small pulley on its axis is placed at the end of a frame, so as to be capable of being rapidly rotated by a wheel and band, when placed between the poles of the electro-magnet; its axis of rotation either coinciding with, or being placed at right angles to, the lines of magnetic energy. When the axis of rotation of the ball coincides with the magnetic lines, there would be obviously no change in the direction of the planes of the assumed molecular revolution, and consequently no heat ought to be developed; this may be shown to be the case by means of a thermopile connected with a galvanometer and brought near the rotating ball. When, however, the axis of rotation of the ball is placed at right angles to the magnetic lines, heat will be immediately developed.

36. The gyratory nature of the magnetic wave is further confirmed by a fact first observed by Faraday—namely, that if a beam of polarised light be transmitted through a piece of heavy glass placed between the poles of an electro-magnet, so that the axis of the beam may correspond with the lines of magnetic energy, then, if the magnet be excited, the plane of polarisation is twisted a little, either to the right or left, according to the direction of magnetic polarity—a result by no means inconsistent with the hypothesis of molecular revolution.

37. In both the essays before alluded to, the "Ether" theory has been put forward as evidence of the divergence of opinion existing between physicists. It must, however, be observed that

the undulatory theory now very generally received assumes only that vibratory motion is transmitted by matter of *some* kind, and the inferences drawn from it are not invalidated by any hypotheses as to the precise nature of the transmitting medium. The writer, differing from many eminent physicists and mathematicians, is inclined to adopt the view that long since had the able support of Leonard Eüler, and was first prominently put forward in this country by Grove, that the hypothesis of the presence of ether instertitially in all kinds of matter is gratuitous.

38. It may, however, be desirable to consider a little more in detail the means by which the various kinds of energy are transmitted. Sonorous vibrations are freely transmitted by all kinds of homogeneous matter, whether in the gaseous, fluid, or solid state; in solid matter not homogeneous the amount of transmission depends upon structure. Thus, the transmission of sound through wood is much less perfect in the traverse than in the longitudinal direction; it is much more impeded by cork, and almost intercepted by cotton-wool and similar substances. Electric energy is more or less freely transmitted by most kinds of matter, except glass, silk, and the resinous products of the vegetable kingdom. Since the transmission of the vibrations of light and heat through an absolute vacuum is obviously impossible, because the transmission of motion implies the presence of matter to be moved, it becomes a necessity that infinite space must be pervaded by some highly elastic and attenuated kind of matter, as the medium of the transmission of light and heat from the central luminaries of all existing solar systems to their attendant satellites. This, in entire and probably unavoidable ignorance of its nature, has been termed "ether," and the existence of ether has been assumed to be demonstrated by the periodic retardation of Enke's comet. But it has been further assumed that ether *alone* is capable of transmitting the vibrations of light and heat, and must therefore exist interstitially in all kinds of translucent and transcalent matter.

39. The only basis on which this *interstitial ether* hypothesis rests is the assumed incapacity of ordinary matter, whether in the solid, liquid, or gaseous state, to transmit the extremely rapid vibrations of light and heat, for no more valid reason than this: that the only vibrations of ordinary matter of which any actual knowledge exists—namely, those of sound—are almost immeasurably slower than those of light and heat, the former being numbered by at most a few thousands, the latter by hundreds of millions of millions in one second of time. But it must be borne in mind that sonorous vibrations are always

longitudinal, in the production of which repulsive forces are *alone* concerned; whilst, on the contrary, light and heat vibrations are necessarily *transverse*, and the production of these is solely due to *attractive* forces. Now, these respective forces obey very different laws, for whilst attractive forces obey generally, and probably universally, the law of the inverse *square* of the distance between the attracting particles, molecular repulsion must obviously—at all events, in gaseous matter—obey the law of the inverse *cube* of the distance, as a corollary to Boyle's law of the constant ratio (within wide limits) of gaseous pressure to density; therefore, from the rates of transmission of longitudinal vibrations, nothing can be predicated respecting the possible rates of transmission of transverse waves. It has been asserted that molecular repulsion is a dynamic resultant effect of molecular vibration, and therefore incapable of expression by a statical law; but it is very doubtful whether molecular attraction is not equally a dynamic sequence, and therefore not a whit more entitled to claim a statical law than the former. This view may be illustrated by an experiment, in which a disc of card at the end of a light suspended rod, and placed near a tuning-fork, is attracted or drawn towards the latter, when thrown into vibration by means of a violin-bow.

40. Sir C. Wheatstone has long since shown that electricity traverses a copper wire at a velocity not less than that of light. Whether electricity be matter or motion, this result shows that the capability of matter to transmit the vibrations of light is by no means improbable. Moreover, it is now generally admitted that when a body becomes heated, its own molecules, and not merely those of the supposed interstitial ether, are thrown into a state of vibratory motion, the amount of heat corresponding probably to the amplitude of the vibrations. If, then, ordinary matter be assumed to be susceptible of heat-vibrations, can any valid reason be assigned for its insusceptibility of light-vibrations, when the close relationship, if not the absolute identity, of these two forms of energy is manifested by so many phenomena common to both, such as those of reflection and refraction, polarisation, and the reciprocal properties of emission and absorption, whether general or selective.

41. The reciprocity between the powers of radiating and absorbing both light and heat which exists in all substances, so far as experiment has shown, presents a cogent argument in favour of the hypothesis that the energies of both light and heat are exerted on the molecules of sensible matter, and not on any supposed interstitial medium. It is a well-established fact that those surfaces of bodies which radiate heat most freely also

absorb most readily—that is to say, that molecular condition which is more or less favourable for imparting to adjacent matter the wave-motion of heat is in the same degree more or less favourable to its reception; and the same holds good with respect to the selective absorption of heat—namely, that any substance absorbs more freely the special kind of heat which it radiates. Thus, while a plate of rock-salt absorbs little more than 3 per cent. of the heat radiated by heated black platinum, it absorbs 30 per cent. of the heat radiated by a piece of its own substance heated to the same temperature. Precisely the same phenomena are observed with respect to light: for example, the scoriæ floating on the surface of a pot of molten metal glow more brightly than the clean surface of the metal; and if an encaustic tile with a pattern on it—say of black and white—be heated red hot, and placed in a dark room, the black portion will be observed to glow much more brightly than the white. In these instances the molecular conditions that facilitate absorption equally facilitate emission; and the case is the same with regard to selective absorption. Thus, a piece of red glass, when heated, emits a greenish light—that is, the absorbed correspond with the emitted rays. And a still more striking instance has been observed by Kirchhoff—namely, that a tourmaline, heated to incandescence, emits light polarised in a plane perpendicular to that which it transmits. Here the structure, that enables the crystal to take up wave-motion in one direction only, compels it to impart motion exclusively in the same direction. If, then, it be admitted that the molecules of all kinds of matter are susceptible of thermic energy, how can it be denied that they are equally susceptible of the energy of light, when the varied phenomena of light and heat are shown to be in all cases precisely analogous.

42. All substances in the state of incandescent vapour are found to originate or emit rays of definite refrangibility, and to form an interrupted spectrum, consisting of bright lines only; moreover, the vapour of every substance is capable of absorbing the rays that itself emits when incandescent—that is to say, of responding to and appropriating those special vibrations of which it is most susceptible. This is readily demonstrated by means of sodium. If burnt in a spirit-lamp it emits only the double D line in the spectrum, and if interposed in a state of vapour, it absorbs the vibrations of the same period, and cuts out the same line from a continuous spectrum. A similar reciprocity of emission and absorption exists in sonorous vibrations. If two harps tuned exactly in unison be placed at the opposite sides of a room, a note struck on one will excite vibrations in the corresponding string, and in that only, of

the other; is it less reasonable to attribute the former phenomena to the special susceptibility of the molocules, than to ascribe the latter to the special tension of the reciprocating strings? It is quite true that incandescent bodies in the solid or fluid state emit rays constituting a continuous, not an interrupted, spectrum. This is no doubt due to the interference of aggregation with the motion to which the molecules are most prone; for it has been observed that the bright lines in the spectrum become more sharply defined by attenuation of the emitting vapours or gas, and that they become broader and less defined by its condensation.

43. It has appeared, from the investigations of Messrs. Huggins and Lockyer, that the periodic time of vibrations emitted by incandescent hydrogen in the vicinity of the sun is sometimes slightly modified by the proper motion of the emitting gas; in this case some portion of the bright line will be slightly deflected towards the violet or red end of the spectrum, accordingly as the waye-length is diminished or increased by the proper motion of the gas; occasionally deflections in both directions simultaneously have been observed, showing the existence of a solar cyclone. A precisely analogous acoustical phenomenon may be demonstrated by placing a free reed at one end of a long hollow rod, and a small pair of bellows at the other end: if the rod be briskly waved to and fro while the sound of the reed continues, its pitch appears to be sharpened to those whom it approaches, and flattened to those from whom it is receding. It follows from these facts, as an irresistible conclusion, that the molecules of ordinary matter are susceptible of the vibrations both of light and heat, and are therefore equally capable of transmitting them; and if so, the hypothesis of the necessity of interstitial ether becomes absolutely groundless. It may be asked how, if ether be admitted to occupy infinite space, it can be imagined to be excluded from the spaces occupied by ordinary matter; to this the writer would reply, by means of a very simple hypothesis, which he ventured to put forward in the introduction to the last edition of his "Elements of Natural Philosophy"—namely, that ether (like its liquid namesake with water) is immiscible with ordinary gaseous matter, and therefore floats above the attenuated confines of the atmosphere; it would thus be not less capable of fulfilling its beneficent mission of supplying organic life with the indispensable energies of light and heat; for, as no limit can be assigned to the *possible* amount of molecular displacement in a medium so attenuated as ether must necessarily be, an amount of energy is conceivable in its molecules which would be sufficient to impart

effective motion to the indefinitely denser forms of cognisable matter.

44. It was objected by Dr. Young to the views here advocated, that if ordinary matter be susceptible of luminous vibrations, all bodies ought more or less to absorb light, and to become luminous, just as all bodies become more or less heated, by absorbing radiated heat. To this it may be replied that a large number of bodies is now known to be phosphorescent after exposure to light; but that in many the duration of that property is exceedingly brief: when enclosed in a glass tube, and placed in a slit in a dark screen, surrounding an electric light, they emit visible light only when rotated with great rapidity, so that the particles may be presented to the eye within the 10th or 20th of a second after their exposure to light. If the velocity of rotation could be indefinitely increased, it is not improbable that all substances would become luminous, for it must be remembered that the 50th or 100th of a second is as an age when compared with the duration of a wave of light.

45. Moreover, matter is equally capable of absorbing the invisible rays, that are known by their chemical effects to be present in the spectrum. This has been shown by the experiments of M. Niepce. An engraving, which has been placed for some days in the dark, is half covered with an opaque screen, and then exposed to sun-light. The engraving is then placed (with the usual precautions of a photographic process) in juxtaposition but not in contact with a piece of sensitive paper. An inverted or 'negative' image of that portion of the engraving which has been exposed to light will be produced on the paper, while the portion that was covered up will produce no effect. Again if the engraving after exposure be placed in contact for several hours with a sheet of white paper not recently exposed to light, and the latter be then applied to the sensitive paper, a faint impression of the exposed portion of the engraving will still be produced.

46. Dr. McCann, having first identified heat and motion as synonymous terms, impugns the theory of latent heat as involving a "contradiction in terms," and it is by no means the first time that that theory has been put forward as a stumbling-block to the dynamic theory of heat. "Latent heat" is an unfortunate and misleading term, and has mystified this writer as well as many others: it ought long ago to have been discarded, together with the material theory of heat, from which it arose.

47. A much better term would be *employed* or *occupied* heat, for the so-called latent heat is wholly employed or occupied in

maintaining the change—first from the solid to the fluid state, and secondly from the fluid to the gaseous. The facts are very plain; a pound of water at the temperature of 0° C., or the freezing point, mixed with a pound of water at 79° yields two pounds at the mean temperature of 39·5°; but a pound of ice or dry snow at the temperature of 0° mixed with a pound of water at 79° yields two pounds of water at 0°, because the 79° of sensible heat in the water are now employed or occupied in maintaining such an amount of vibratory motion in the molecules of the ice, that they are no longer able to obey that polar attraction by which they were previously aggregated together in given directions in a crystalline form (for though not so evident in ice, the crystalline character of snow is notorious), and the heat-energy, being thus already occupied in doing work, is incapable of doing any other work, as for example on the organs of sensation, at the same time. The same reasoning applies to the change from the fluid to the gaseous state; but in this case a much larger amount of thermic energy is employed in so far removing the molecules from the sphere of each other's attraction, that the balance of their mutual forces is repulsive, and so long as that repulsion is maintained, the dry steam manifests all the properties common to the fixed gases. "Latent" heat, then, when properly understood, ceases to be a "stumbling-block to the dynamic theory of heat."

48. Several quantitative equivalents of energy have been assigned by experiment, but that on which most stress is laid is the equivalence of thermic and kinetic energy. It is a remarkable and unprecedented confirmation of the thermo-dynamic theory, that the numerical results arrived at by three distinct methods of investigation, in the hands of as many independent physicists, should be found to agree within very narrow limits of error.

49. He must be a bold man who denies that the sun shines at noonday; and scarcely less audacious is the assertion that the experiments of Dr. Joule do not confirm this equivalence. Dr. Joule conducted four distinct series of experiments, three series on the amount of thermic energy produced by molecular friction in stirring respectively water, oil, and mercury; the fourth, on that produced by the friction of two iron surfaces against each other. The four numerical results accorded very nearly, and after assigning to each result its weight, according to its estimated liability to error, he deduced the mean value of 772 foot-pounds as the dynamic equivalent of thermic energy.*

* For the sake of those who are not already familiar with this subject, it may be stated that a foot-pound is the amount of energy acquired by a weight of one pound in descending through the vertical space of one foot,

In the metrical system, in which the units of quantity are one kilogramme, one metre, and one degree in the centigrade scale, the above equivalent is represented by 424 dynamic units, which, for brevity's sake, we may as well agree with the French in calling "dynams."

50. It has been found by experiment that a less amount of heat is required to raise a gas maintained at a constant *volume* one degree of temperature, than when the gas is allowed to expand under a constant *pressure*. Suppose, for example, that the gas be inclosed in a vertical cylinder under a piston of 100 square inches area, the atmospheric pressure on this piston will be 1,500 lb., and the raising this piston is equivalent to raising a weight of that amount. Dr. J. R. Mayer, assuming that the difference in the quantities of heat in the two cases above mentioned is equivalent to the work done by the expanding gas, proceeds to determine the numerical value of these equivalent quantities. Taking the specific heat of air to be 0·267, as at that time determined by the observations of De la Roche and Berard, he found the dynamic equivalent of an unit of thermic energy to be 367 dynams. But if, in the calculation of this number, the more careful and accurate subsequent determinations of the specific heat of air by Joule and Regnault be substituted, namely, 0·2375, the result gives as the equivalent 426 dynams; a result almost identical with that of Dr. Joule, but based on theoretical considerations only.

51. M. Séguin pursued a course of observation exactly the reverse of that of Dr. Joule, namely, to determine the amount of heat converted into work in the steam-engine. Taking it as an axiom, in strict accordance with experimental facts, that the difference between the heat existing in the steam as it enters the cylinder, and that remaining in it after its exit, must be the thermic equivalent of the work done in and by the engine, (which difference, in the best constructed engines, amounts to about five per cent. of the total heat due to the combustion of the fuel,) he assigned a value to the thermic unit. Subsequently, M. G. A. Hirn, pursuing the same course, with the aid of more perfect instrumental means, determined the value of one thermic unit to be 425 dynams; a remarkable result, and intermediate between those previously inferred by Mayer, and obtained by Joule. In the face of such overwhelming concur-

---

or, in other words, the amount necessary to raise one pound one foot; and the numerical equivalent here given means that 772 dynamic units are equivalent to the amount of thermic energy required to raise the temperature of one pound of pure water, at or about the mean temperature of the air, one degree of Fahrenheit's scale.

rent evidence, will any one be still bold enough to assert that the conservation of energy is a myth?

52. Examples without number might be adduced of the conservation of energy, in which the equivalence has not yet been, but probably ere long will be, determined quantitatively; but a few must suffice. Whenever resistance is offered to the passage of an electric current, heat is generated in proportion to the resistance in the circuit, and the heat is evolved at the expense of current, that is to say, there is a transformation of electric into thermic energy; and this may exist in any degree, from the least perceptible elevation of temperature in the conductor, to its actual deflagration and volatilisation, as in the carbon points of an electric lamp, or the deflagration of gold-leaf by the discharge of a Leyden battery. And it has elsewhere been shown by the writer* that under suitable conditions the converse transformation of heat into electricity takes place. If the adjacent ends of a bar of antimony (*a*) and one of bismuth (*b*) be soldered together, it has long been known that when a sufficiently weak current of electricity is transmitted through this thermo-electric element passing from *a* to *b*, heat is produced at the point of junction, but if passing in the direction from *b* to *a*, cold is produced; but when the element is placed in a Wheatstone's bridge, the galvanometer shows a loss of current when heat is gained, and a gain of current when heat is lost. This leads irresistibly to the conclusion that an interchange of thermic and electric energy takes place at the point of junction of the two metals. It may be observed that bismuth presents this property in a higher degree than any other known substance; and it is altogether a remarkable metal, excelling also in the property of diamagnetism, and sharing with water the property of expanding on passing from the fluid to the solid state by cooling.

53. The dynamo-electric machine is another conspicuous example. While at rest it manifests no properties either of electricity or magnetism, but when kinetic energy produced by the muscular force of the arm is expended in turning the winch of the machine, magnetism is produced, and the electro-magnet becomes active; this again induces an electric current in the revolving armature, which in its turn becomes light and heat in a platinum wire, through which it may be transmitted; or if employed in doing any mechanical work, it becomes kinetic energy.

54. Lastly, the sense of vision may be quoted as a highly probable example of the conservation of energy, it being not inconsistent with any known fact to suppose that the action of light on the retina is a true photographic process, not per-

---

* *L. E. and D. Phil. Mag.*, vol. xxxii., p. 378.

manent, as that produced on the salts of gold and silver in ordinary photography, but generally as transient as the ray which produces it; and that this chemical action is resolved into electric energy, which is transmitted by the optic nerve to the brain. That the duration of the impression on the retina is proportional to its intensity, any one may convince himself by looking at a bright light, and then closing the eyes, when a bright image will for a longer or shorter period, according to the intensity of the light, remain visible.

55. The principle of the dissipation of energy, as a corollary to that of its conservation, has of course been equally ignored; but it must here suffice to give a familiar illustration, both of the conservation and the dissipation of energy, in the action of the rifle-ball. This reaches the target with less velocity, and consequently with less energy, than it possessed on leaving the muzzle; a portion of its energy has been expended in producing heat by friction against the particles of air between which it passes, which is dispersed through the surrounding atmosphere, and thus becomes *dissipated*. On reaching the target the progressive motion of the mass is arrested, and converted into molecular motion, which is cognisable only as heat, by which the mass is reduced to the fluid state, and splashes of molten metal are scattered in all directions. These again impart their heat partly to the air through which they pass, partly by radiation into space, and partly to the ground on which they fall; and thus the whole energy of the ball becomes dissipated. An analogous explanation will apply to all other cases of the dissipation of energy.

56. In the two essays above-mentioned, the objections of their authors to the validity of the correlation and conservation of energy appear to the writer to lie, not against any observed facts, or their mutual relations, but exclusively against the vague or illogical terms in which the interpretation of them has hitherto been expressed by physicists. Mr. Moore having, in consequence of a published remonstrance, withdrawn his unfair criticism of the writer's explanation of "latent" heat,* he is glad to embrace the present opportunity of withdrawing with equal publicity, any imputation he may have made against Mr. Moore's literary candour; the publication of a short letter containing that withdrawal having been declined by the journal in which the remonstrance was published. At the same time it cannot be denied that this writer has grossly misrepresented the course of philosophic thought pursued in regard to many problems in physics, especially those relating to the transmission and transformation of energy.

---

* *Elements of Natural Philosophy*, sixth edition, p. 786.

57. Dr. McCann writes (§ 25) in relation to potential energy, "this sounds plausible enough while we use the mystic word energy, but as it is motion with which we are at present concerned, we shall use that word instead." Now, firstly, there is no mystery about energy if only it be properly understood, and secondly, the gratuitous substitution of the term "motion" for "energy," would inevitably make nonsense of everything that has been, or indeed can be, written on the subject. It appears, moreover, from the contents of the same page, that the author's views of causation are as illogical and inconclusive as he holds the sentiments of physicists to be. He puts the case of "a heavy book nicely balanced on the edge of the table; the slightest touch of my finger causes it to fall to the ground." But the fall would not result from the slightest touch *unless the book were in a position of unstable equilibrium;* neither would it result from the unstable position *if the touch did not ensue;* the touch, therefore is no more entitled to be called *the* cause of the fall, than the unstable position: both are conditions precedent, but the cause of the fall is the attraction of gravitation.

58. Again, he instances the explosion of a mine by a match held between the finger and thumb, and then contrasts the amount of energy expended in moving the finger and thumb, with the amount developed by the explosion, as though there were any conceivable connection between them, in relation to cause and effect; the match might just as well be supposed to be attached to a steam hammer, and by its descent to explode a single grain of gunpowder, when the balance of the employed and resulting energies, which he pleases to call motions, that is, of the assumed *cause* and *effect,* would be all the other way. Dr. McCann speaks of the applied match as the cause of the explosion,—it may be so in a popular sense, but is the expression logically accurate? It is presumed not to be so. Two little heaps of black granular powder are lying on the table, one happens to be gunpowder and the other coal-dust; a lighted match is applied to each in succession, one explodes, the other remains unaffected: is the match a whit more *the cause* of the explosion of one heap, than of the non-explosion of the other? The application of heat is a necessary condition of the explosion, but the "cause" of both results is alike the chemical constitution of the respective kinds of matter: the potential energy of chemical affinity, that exists in the former, but does not exist in the latter substance. A similar discussion of all the views set forth in these essays would lead to a wearisome dissertation, far beyond the limits of a paper readable before this Society; but it is a grave question, whether if the amount of *mental*

energy, that has been expended in burlesqueing *physical* energy had been devoted to obtaining a fuller comprehension of the subject, the cause of truth might not have been more efficiently promoted.

59. Two further points only of Dr. McCann's paper will here be remarked upon. The quotation (§ 20) from Mr. Spencer's *First Principles* is an elaborate but, to my mind, confused statement of the perfectly distinct and definite ideas of *absolute* and *relative* motion. He writes—"A body impelled by the hand is clearly perceived to move, and to move in a definite direction," *i. e., relatively to the perceiver* and surrounding objects, beyond which perception cannot extend, for the *perception* must obviously be the same whether the observer were absolutely at rest in space, or whether he and the observed body partake alike of the earth's rotation on its axis and revolution round the sun, and the progression, if any, of the entire solar system in space, and any other motion or motions, conceivable or inconceivable—and that is the whole question.

60. In reference to Mr. Spencer's gratuitous assumption (§ 1) that the various forms of physical and mental energy are reciprocally convertible, he writes (§ 41):—"That such is a fact may be assumed but can never be proved till some instrument be constructed capable of measuring the velocity of thought;" evidently not being aware that such an instrument had been constructed some years since, and satisfactory experiments made by Drs. Hirsch, De Jaager, and Donders; * but they afford no confirmation of Mr. Spencer's assumptions, beyond the fact that time is an element in mental operations; but until the precise train of physical changes in the brain and nerves which accompanies perception and thought can be fully ascertained (an amount of knowledge obviously beyond the reach of man), the hypothesis in question must be held to be insusceptible of proof.

61. It may, in conclusion, be remarked with much regret that the principle of the conservation of energy has by some been misapplied to questions far beyond its legitimate scope, in a fruitless endeavour to supersede the necessity of an omniscient Creator. To the mind of the writer, and, it is earnestly hoped, to that of most of his hearers and readers, the indisputable establishment of this principle conveys only a more exalted idea of that infinite wisdom by which the perpetually recurring transformations and interchanges, not only of the materials, but also of the powers, of Nature are rendered subservient to predetermined laws, which govern the comfort and welfare of all created

* *Elements of Natural Philosophy*, sixth edition, p. 568.

beings. It is a sad miscarriage of the powers of human reason, when those who have laboured most assiduously in unravelling the higher mysteries of physical causation are not thereby brought nearer to their Creator, that:—

> "Those earthly godfathers of heaven's lights,
> That give a name to every fixèd star,
> Have no more profit of those shining lights
> Than those who walk, and wot not what they are."

61. The bearings of Evolution, Conservation, and Continuity on the higher relations of man to his Creator must be left for a future communication, to which the title of "Scientific Materialism" may be not inappropriately applied.

The CHAIRMAN.—It is now my duty to move that the thanks of this meeting be given to Mr. Brooke for his very able and scientific paper. Certainly, if Mr. Brooke and the discussion, which is now about to take place, can do anything to remedy the "confusion worse confounded," which at present pervades the scientific and philosophical world in regard to the use of the terms "force" and "energy," a great deal of good will be done, for I confess that as matters stand at present, I never hear the words used without finding that there is a great amount of confusion and uncertainty in their application. I may mention that strangers who desire to do so are invited to take part in the discussion; but as, to-night, there happens to be present one who is pointedly referred to in Mr. Brooke's paper, I think I shall consult the feelings of the meeting if I ask him to open the debate, after our Honorary Secretary has read a written communication from Dr. M'Cann.

CAPTAIN F. PETRIE then read Dr. M'Cann's communication as follows:—

I AM glad to find that Mr. Brooke agrees with me in my condemnation of the way in which physicists, for the most part, speak of force, energy, and motion. As he also differs very much from the theories of Professor Tyndall, and the other physicists I have quoted, and has only taken up and fully discussed the statements in §§ 59 to 61 of my paper, there are, consequently, only a few points which I have to notice in his valuable essay.

Conservation of energy, if *limited* by an Almighty will, need not, I grant, lead to the results I have named; but if unlimited, or actually conserved, these results seem a necessary sequence, as is evidenced in my references to those who affirm the existence of these results.

He states (§ 14) that "the theory of the conservation of energy implies that no kind of energy *can* be produced by human agency, except at the expense of an equal amount of the same kind, or an equivalent amount of some other kind of energy." From this it surely follows, in opposition to his next sentence, that the total amount of energy in the universe remains not only un*changed*, but un*changeable*; which is the usual meaning of the theory, although apparently not that held by Mr. Brooke. If the total amount of energy be changeable, ought not the words to be that "no kind of energy *is* produced?" The corollary of this view of conservation, is the truism condemned by Sir John Herschel, for if an energy that is not kinetic is potential, it is at once evident that the sum of both must be always equal. In § 29 we are told that "light and heat have frequently been illogically designated by able physicists simply as 'modes of motion.' This appears to have led many into a confusion of the terms 'force,' 'energy,' and 'motion.'" Of course when I followed Professor Tyndall's reasoning about heat as, not designated only, but actually being a mode of motion, I was obliged to follow him also into the hopeless confusion to which such reasoning must lead. I only followed him, however, that I might expose the confusion; but by no means share it. It is well that Mr. Brooke holds sounder and more logical views. Still, after this, he should not charge me (§ 59) with "the *gratuitous* substitution of the term 'motion' for 'energy,'" nor say (§ 46) that I "having first identified heat and motion as synonymous terms, &c.," as though the identification were mine, when it is Tyndall's.

My views of causation are somewhat severely spoken of (§ 58), because I say the touch of my finger *caused* a book to fall to the ground. As I was not concerned at the moment with the theory of causation, I used the word in its popular sense; *occasioned* would have united my purpose equally well in both illustrations, as the argument is not in the least affected by either word. I fear, however, Mr. Brooke is even as illogical as I am myself in this case, for while defining the causation, he says "the cause of the fall is the attraction of gravitation." This is not correct, inasmuch as the cause was my wish to overturn the book, the attraction of gravitation being only, like the unstable equilibrium, a necessary condition. If there be shown any burlesque of physical energy in my paper, as is implied in the remarks in § 37, I will gladly withdraw it. So far as I am aware, any criticisms to which that term could be applied, are in the fancies of those who, while accurate observers, are but indifferent theorists; of those who, to use Mr. Brooke's own words, would misapply the conservation of energy "in a fruitless endeavour to supersede the necessity of an omniscient Creator."

JAS. M'CANN.

Rev. JOHN MOORE.*—I thank you, Mr. Chairman, for the permission you have granted me to take part in this discussion, and, in availing myself of the privilege, I wish it to be distinctly understood that it is not as a physicist but as a metaphysician, that I approach this question. For me, the doctrine of the conservation of energy had no special interest until, some six years ago, I read an article, by Professor Tyndall, in the *Fortnightly Review*, wherein he employs this theory to prove the futility and folly of prayer. This led me to make a most careful examination, and I found that the theory of conservation required of those who would accept it assumptions directly opposed to some of the best-established truths of philosophy. One of its main pillars is a doctrine of causation, associated with the names of Hume, Brown, and Mill, which I am convinced is false. We are asked to believe that the relation of cause and effect is nothing more than a time-relation among events, and, consequently, that the very important term "Power" does not symbolize anything in the nature of the cause fitting it to produce the effect, but denotes mere antecedence. Hence, to repeat the often used but still powerful illustration of Reid, it is quite correct to say that day is the cause of night, and night the cause of day. But, in reply, I ask what do men mean when they speak of the cause of a specified change? Are they

* Author of the article in the *Quarterly Review* called "Heresies of Science," referred to by Mr. Brooke. I regret to have to record Mr. Moore's decease, which occurred before his remarks were in print.—*Ed.*

satisfied with that account of the origination of an event which simply refers it to another event immediately preceding? Can the human mind, in its self-impelled search for causes, stop short of anything other than reality, endowed with powers enabling it to produce certain effects? An examination of our judgments concerning the realities presented to us, reveals the fact that we are compelled to think each of them as possessing a given constitution, as endowed with certain "qualities" and "powers." These judgments we must accept as the starting points of thought; their validity cannot by us be determined in the light of higher truths; to us they are ultimate. Turning to the world of matter, let us begin with the atoms themselves—what, by the very laws of our intelligence, are we compelled to think about them? First, we think that each atom possesses certain "qualities." These all have relation to space, and constitute the "primary" qualities of the metaphysician. Second, we think the atoms to possess also certain "powers," whose existence we apprehend not immediately as we do that of the qualities, but only mediately or through their effects. Now, since each atom has both qualities and powers, the theory that matter is indestructible, embraces two things:—

(1.) The conservation or persistence of material qualities.

(2.) The conservation or persistence of material powers.

To regard these two doctrines as separable is unphilosophical; they are but different aspects of the one truth concerning the indestructibility of matter by human agents. That this is so, is evident from the fact that is impossible, even in imagination, to separate the powers from the qualities, as associated together in the most elementary form, of material existence. In this connection Faraday's words are very important and significant. He says: "A particle of oxygen is ever a particle of oxygen; nothing can in the least wear it. If it enter into combination, and disappear as oxygen; if it pass through a thousand combinations—animal, vegetable, and mineral; if it lie hid for a thousand years, and then be evolved, it is oxygen with its first qualities neither more nor less. It has all its original force, and only that." To-night, Mr. Brooke has told us that "in cases of percussion, the energy of a striking body may be more or less imparted to the body struck." But is not this statement wholly inconsistent with the doctrine of the indestructibility of matter? If, when an atom of oxygen exerts one or more of its powers, there is a transference of energy to some other reality, does it not then cease to be a particle of oxygen? "Energy," says Mr. Brooke, "was first defined, by Thomas Young, to be "the power of doing work," and this definition does not appear to require any amendment." Now, if by "work" is here meant the mere displacement of matter, either molecularly or in mass, the distinction between force and energy is not a valid one. Take any power—mental, vital, or material: we find that we are able to think it either as unexerted or as exerted; in other words, as power "at rest," or power "in action." To denote the latter, philosophers have employed the term energy; so that energy is not the power of doing work, but power doing work, power in work (ἐν ἔργον). But this is not the only case in which we think error has crept in through confusion and misuse of terms. In the Introductory Chapter of the last edition of his valuable treatise on Natural Philosophy, Mr. Brooke refers to the numberless facts which, since the publication of the fifth edition, had been observed and recorded, "all tending to confirm the opinion that the various 'physical agents' are not forms of matter, but 'modes of motion.'" Mr. Justice Grove tells us that if we attempt to analyze our conception of force, viewed as the cause of any perceived motion, we can get nothing beyond some antecedent motion. And Professor Tyndall asserts that "the cause of motion itself must be motion." No wonder that Mr. Mill has so readily accepted the doctrine of the conservation of energy! In the eighth edition of his "Logic," published within the last month, he gives us his own statement of it with marvellous but, in this case, fatal clearness. Stated in a few words, the theory is as follows:—"That the conservation of force is really the conservation of motion; that in the various interchanges between the forms of force, it is always motion that is transformed into motion." ("Logic," vol. i., p. 404.) Now, to the theory of the conservation of energy, I oppose the conservation of power; the power or force in the universe is a constant quantity, but the amount of motion is not the same for two successive moments, while for the theory of the transmutation of energy I substitute that of the correlation of powers. Powers are often correlated in the sense that the action of one supplies the condition of the action of another. I will to move my hand, and the motion immediately follows; this is an instance of correlation. "I" am the cause of my volition: the volition itself is not the cause of the action of the physical powers which immediately determined the movement of the hand, but merely a remote condition. The conscious volition and the observed movement of the hand are merely the first and last members in a series of an unknown number of effects. In a conversation with Dr. Carpenter on these subjects a few weeks ago, I put the question whether, in a case like the above, the motion of the hand is to be considered as a transmuted volition. "Certainly not," he replied, and agreed with me that the volition is merely a condition, not the cause, not even a remote cause of the movement. Some of Mr. Brooke's remarks on my opinions have raised another question, to which I can discover no satisfactory answer. Why should he and other physicists constantly denominate as "material" those theories which they wish to contradistinguish from their own, the so-called dynamical? Even Tyndall admits that we cannot have motion without some form of "matter" moving. Hence, having thrown overboard the imponderables, physicists have been compelled, with the aid of the scientific imagination, to seek for some kind of material basis which shall take their place; and now we have an "ether" filling stellar space, and permeating all ponderable bodies. From Professor Tyndall we learn that this ether is a jelly-like substance, and is marvellously elastic! Mr. Justice Grove, however, regards the assumption of any such material basis as unnecessary, for, in his opinion, it requires no great stretch of imagination to conceive light and electricity as motion, and not as things moving. Once more, I regard the introduction of the term potential energy into the vocabulary of science as nothing less than a calamity. What is the reality symbolized by these words, and where is it to be found? A simple illustration will serve both to indicate my objection to the use of the term potential energy, and also to bring out my own view. Here are two stones, each of them at the surface of the earth, weighing one pound. One of them I place close to the edge of the mouth of a coal-pit, one hundred yards deep; the other I throw upwards, which, at its maximum height of one hundred feet, is caught on the ledge of a rock. Now the theory of the conservation of energy requires us to believe that the latter stone has, by rising, acquired a potential energy—a power of doing work of which the one remaining on the ground is altogether destitute. The stone resting on the rock can fall, while —so says the theory—the stone on the edge of the pit cannot. Mr. Brooke has referred to Dr. Joule's experiments. I will only say that in none of these as explained to me by Dr. Joule himself, can I find anything opposed to the positions I have been maintaining. The beautiful experiments by which he determined the mechanical equivalent of heat, I am prepared to show, lend no support whatever to the doctrine that the various forms of energy are mutually convertible. In conclusion, I would, sir, thank Mr. Brooke for his able criticism of my opinions as given in the paper this evening, and elsewhere. Every intelligent and sincere objector I ever regard as a true friend, both to myself and the great cause of truth.

Rev. W. J. Irons, D.D.—I think the paper which has been read, and the observations which have since been made upon it, are so important that they need careful and minute consideration; and a hasty discussion on a subject of so much depth and importance would scarcely be becoming in a scientific Society like this. For my own part, I feel strongly disposed to acquiesce in the distinction which was drawn by the last speaker—namely, that there is indeed a conservation of power, but not a conservation of energy. I think that the conservation of power he refers to is almost identical with the doctrine of Albert and Thomas Aquinas concerning the impossibility of either augmenting or diminishing the sum-total of the physical universe—the impossibility, for instance, of annihilation, affirmed by Albert the Great in very distinct terms. I made up my mind some years ago, when I first considered the doctrine of the "conservation of forces," that it meant no more than had been understood under other terms in the middle ages; but probably at the present moment we are unable to decide what some gentlemen ultimately mean when they lay down the law so positively about this "conservation of forces." Is there no initiation of motion? If Mr. Stuart Mill were here to-night, he might perhaps be able to tell us whether he allows any such thing as a kind of initiation of action which is not a deduction from previous forces in the universe. That would at once raise the question whether materialism be the sum-total of the universe. I should hope he would hardly go that length. Scepticism itself would assist him there, as it would scarcely propound what would be almost a negation of mental action itself. The whole subject is one which we are right in considering with gravity. The philosophy of the subject has yet to be dealt with. Science is the ally of real theology and the handmaid of philosophy and truth, and we must be careful not to rush in suddenly with contradiction of anything that may prove to be scientific truth; but at the same time we are also careful, and we wish our scientific friends would be equally careful, in not adopting as scientific conclusions statements or theories which may be overturned to-morrow. We have had enough of that already. Some people are over-hasty, but we desire to be cautious, because we are lovers of truth. I am sure we shall all profit by the exact and considerate essay of Mr. Brooke, and I think we shall find some admirable corrective thoughts in the speech of Mr. Moore. For my own part I have a hankering after Thomas Aquinas and Albert the Great, who I think may yet put us right.

The CHAIRMAN.—I hope some gentleman will direct his attention to that part of Mr. Brooke's essay which deals with the definition of "force" and "energy."

Mr. A. V. NEWTON.—I quite agree with Mr. Moore that "conservation of energy" is a most unfortunate expression; if we employ in scientific investigations words that are used in common parlance, I cannot help thinking that we should use them according to the meaning they have in common parlance. I think that if a word has taken a new meaning, a writer should adopt that meaning in his writings. There is the word "prevent," for instance, which has two distinct and quite opposite meanings; and here in this paper we have "energy" and "force" defined in three ways.

Mr. BROOKE.—I quote two or three, but I only give one myself.

Mr. NEWTON.—Mr. Brooke's definition comes to this, that "force" is action between particles of matter, by which they are either attracted towards or repelled from each other." That may be a very good definition, but according to my view force is really not action—it is something quite distinct from it, or at all events it may be. I think there is force in gunpowder while it lies quiescent, and there is active force when it is exploding. It would be as well to refer to what are the ordinary definitions of these words. Dr. Johnson gives a number of definitions of force, such as "strength, might, active power," and so on. Now it seems to me that force is or may be a quiescent power. Dr. Johnson gives, as a definition of energy, "power not exerted in action," so that we get a confusion here which it is very desirable to have cleared up. If energy be "power not exerted in action," then Mr. Brooke's use of "energy" and the conservation of "energy" would certainly be correct; and I cannot see any objection to it, for it would amount to precisely the same thing as that "conservation of power," of which Mr. Moore spoke.

The CHAIRMAN.—This is Mr. Brooke's definition: "the power of doing work."

Mr. NEWTON.—Then that quite agrees with the definition I have quoted, and it seems to me to be precisely the same sense in which the word "power" is used by Mr. Moore. Therefore I cannot see any difference between him and Mr. Brooke.

Mr. Moore.—But there is a material difference.

Mr. Newton.—I have ventured upon a definition of force as being "a power" by which changes, whether of position or of condition, are produced. But if "energy" be power not exerted in action, then I see no difference really, between that word and "force" and "power," and we get into a confusion of terms.

Rev. P. Strutt.—It seems to me that there is a difference between Mr. Brooke and Mr. Moore. I understood the last speaker to introduce the idea of mental power as quite distinct from the physical power with which Mr. Brooke dealt. But if the conservation of force and power extend to mental power, then the introduction of any human being into the world is the introduction of a new force into the world (the human will originates action, and with the augmentation of persons there is augmentation of power), and when you take that idea, you open up a new metaphysical field altogether. It appears to me that that should be distinctly kept in mind if we are to deal with the physical question.

The Chairman.—I apprehend that Mr. Brooke deals exclusively with the physical question. It is difficult to say where it infringes on the mental question.

Dr. Irons.—May we catechise Mr. Brooke?

The Chairman.—I think we are fully entitled to ask him to explain his terms.

Dr. Irons.—Then I should like to ask him one or two questions. First, how these ultimate atoms—so to speak—are supposed in his philosophy to work? Do they work in right lines, on the north, south, east, or west of each atom? How did they get their original direction, and how do they afterwards carry out the original idea according to which they began to move? Take the leaves of the plane-tree, for instance; they are all formed on one model, so that an observer may see at once whether a given leaf is the leaf of an oak or of a plane-tree. The original atom began to obtain motion somehow, and I want to know if that motion was in a direct line?

Mr. Brooke.—We know nothing whatever about atoms. It is all pure conjecture, and therefore when you ask me what the atoms do, I tell you distinctly that I know nothing about them.

Mr. Moore.—I have always felt that the battle would have to be fought there, and I asked an able physicist, "Do you not put the whole of the doctrine of the conservation of energy upon the doctrine of atoms?" His reply was, "Certainly I do." We know nothing at all about matter and motion, but we have various forms of motion, and these are the forces of the atoms. That is the whole basis of the conservation of energy." Though Mr. Brooke may assert nothing on this point, other physicists do. Mr. Croll has written a paper in the *Philosophical Magazine* on this subject—as to what is the cause of molecular motion in reference to these atoms.

The Chairman.—Mr. Moore surprised me in his previous observations, by seeming to intimate that colour was a quality of the atoms.

Mr. MOORE.—Not a quality. The physicist I have referred to said to me, "The ultimate atoms differ in quality only so far as shape and size go." I asked him, "Do you not admit colour to be an essential property?" but he replied, "No, that is a sensation, an idea"—calling colour a sensation.

The CHAIRMAN.—At any rate, colour, as we know it, is simply an impression upon the optic nerve communicated to the brain.

Mr. MOORE.—No.

Mr. BROOKE.—Oh, certainly yes.

The CHAIRMAN.—The conception in the mind is the combined result of our sensations, and the external reality. We cannot say that the external reality is the same as our sensations; there is a cause, external to my mind, which causes certain perceptions of it, but on my optic nerve. This is an unquestionable truth. I take up this piece of paper, it seems to me quite absurd to say that its colour, as I see it, is in the piece of paper, though I am quite ready to admit that there is something in the paper which causes the particular sensation, which is quite another question. But I understood Mr. Moore to say that colour is a positive quality in the external thing itself.

Dr. IRONS.—Perhaps I may be allowed to continue my catechising. I want to know whether forces proceed in right lines. How do they go? Are they circular, or direct, or gyratory, or what? Do they go straight on, and, if not, what gives them any other direction? I am now assuming in my question that force can certainly do something. How does it do it? And is there anything afterwards to modify it and give it shape?

The CHAIRMAN.—I should like to ask Mr. Brooke a question before he replies. Will he undertake to discriminate between power, force, and energy, according to his own views?

Mr. BROOKE.—In reply to the last question, I would say if you will define power, and what you mean by it, for I do not know what the definition is? I will draw a distinction if I can. Until then I do not know what I am talking about. I have not defined power, though I have defined force and energy. With regard to the question put by Dr. Irons, as to the direction in which force goes, it is quite clear that I have defined force to be essentially either an attraction or a repulsion—that is to say, either a push or a pull—between two particles, whatever they may be, or masses or portions of matter. It is either a push or a pull. It cannot go anywhere; it is an existence. You cannot talk of its "going" in any direction. In reply to previous observations that have been made, I will first take Dr. M'Cann, who objects to my strictures upon his view of causation, and says they are wholly defective; because, to take the example he quotes—the case of a book falling to the ground—it is not the force of gravitation, but it is his will which causes it. Well, if that be so, suppose instead of willing that the book should go down on the floor, I willed that it should go up to the ceiling. Would that make it do so? My will clearly is not the cause of its falling; it no more descends than it ascends by my will. We have been told that there are certain people who profess to will that a book should go up to the ceiling, and that it does go up. I know that is stated, but I do not believe it. I must maintain, then, that the objections to my views of causation are not supported by any observations with which Dr. M'Cann has favoured us. With regard to Mr. Moore, he says he speaks as a metaphysician, and not as a physicist. Now, I maintain that, in the discussion of physical questions, if metaphysics come into collision with the inexorable logic of facts, so much the worse for the metaphysics ; they must fall to the ground.

Mr. Moore.—Oh, no.

Mr. Brooke.—The world will be controlled by the inexorable logic of facts, and not by any metaphysical disquisition offered in opposition to the facts.

Mr. Moore.—So much the worse for the facts.

Mr. Brooke.—Mr. Moore spoke of night as the cause of day. Now that is really an idea of causation which produces no impression at all upon my mind.

The Chairman.—That was in reference to Mr. Mill.

Mr. Brooke.—Well, at all events, it is not admissible. He laid a great deal of stress on atoms, and upon their nature. I have already stated that we know nothing of their nature. Again, he spoke of atoms subsequently, and of colour being a property of atoms. There is no question about it, colour has nothing to do with atoms at all ; it is an impression produced upon the sensitive organs of the eye by vibratory motions of particular periods. A vibratory motion, comprising a certain number of vibrations in a second, produces upon the eye the impression of blue ; another number of vibrations in a second produces the sensation of yellow ; and another number produces the sensation of red. All this has nothing to do with atoms at all. Then Mr. Moore spoke of sound as motion, and asked why it was that we could not see a sound. For this very simple reason, that the vibratory motion which leads to the perception of sound is a vibratory motion of one character, while the vibratory motion which produces upon the eye the perception of light is a vibratory motion of a totally different character, and the reason why we cannot see a sound is that the vibratory motion which produces it is not capable of affecting the eye, and therefore of producing any sensation in the organs of vision : that is the simple explanation of the matter. Then Mr. Moore has quoted a remark of my own from the introductory chapter in the last edition of my " Elements of Physics." He should not have quoted that passage, for I have now expressly stated in this paper that I have modified some of the views I there expressed. Following the example of some of our most eminent physicists, I spoke of light and heat as not having a material existence, but as being modes of motion, and that is one of the expressions which I have in the present paper taken exception against, as being logically inaccurate. Having stated that, I do not think it is quite fair of Mr. Moore to quote that introduction to which I have referred, as in opposition to what I have stated in this paper, for that is one of the points upon which I have modified my views. I did not then see, as I do now, the force of the objection to it, and which objection I have pointed out in this paper. Then I come to Mr. Moore's ideas about throwing the imponderables overboard, and here I must say that he seems to have failed to represent my views accurately. The imponderables which have been thrown overboard are the supposed material atoms which constitute light and heat. As I have already explained the views once entertained were that there were material particles or atoms projected from the hot or luminous body ; but the undulatory theory declares that light and heat consist in the perception of certain kinds of vibratory motion.

Dr. Irons.—The vibratory motion of the ether?

Mr. Brooke.—That is another question. It is not necessary to assume the existence of ether interstitially deposited in all kinds of matter to convey impressions of light or heat: the particles themselves will do it.

The Chairman.—Mr. Brooke has distinctly stated in his paper his belief that ether does not pervade ordinary matter.

Mr. Brooke.—I have stated that there must be some material medium pervading infinite space by which the vibrations constituting light and heat are conveyed from the centres of systems to their surrounding satellites ; but we are ignorant as to what that is. This medium has been termed "æther," but what its nature may be I do not pretend to say ; I only take it to be matter of some kind in an exceedingly attenuated condition. The term "jelly-like" which has been applied to it has been taken up sarcastically by some, but it merely means this, that the mechanical properties of the ether more resemble the mechanical properties of a jelly than those of a gas. It means nothing more than that gas and air have certain mechanical properties, while gelatinous substances have certain other mechanical properties, and that the mechanical properties of ether more resemble the mechanical properties of a jelly than the mechanical properties of a gas :—there is nothing more meant than that. Now with regard to the potential energy, or "energy of position," in the stone to which Mr. Moore objected : a stone put up upon a shelf has a potential energy which a stone upon the ground has not. Let them both fall down the mine, then the one dropped from the shelf above will fall with greater velocity than the other. It has acquired a power which enables it to fall with greater velocity than the other. That is the simple meaning of potential energy—the energy which the stone acquires in being raised from the ground. As to the "conservation of power" I cannot say anything. Before I can deal with that, I must ask you to define power, and when I know the definition I will say whether the "conservation of power" is the same thing as the "conservation of energy."

Mr. Moore.—May I say one word? Power cannot be defined. The truest definition is "power is power," and that is all ; but every one knows what it is. Before I put forward a volition, I am conscious that I have the power to do it. But it does not admit of definition.

Mr. Brooke.—I take it, then, from Mr. Moore's own lips that "power" is indefinable. Then the "conservation of power" means the conservation of something indefinable, but the "conservation of energy" means the conservation of something that is defined. I think it is a great pity to introduce into anything that pretends to be accurate logical discussion, terms which we cannot and do not define, because when we do that, we do not know what we are talking about. We can predicate nothing respecting it, if we do not know what the word means: I therefore decline to make any observations about the conservation of power. I think Mr. Newton will now see the ground of the difference between Mr. Moore's and my views. An observation was made about vibratory motion as the force of atoms. Now, force is one thing; vibratory motion is a totally different thing; and atoms we know nothing about. If I am told, therefore, that vibratory motion is the force of atoms, I cannot understand it. It conveys no idea to my mind. The gist of Mr. Moore's objections to the definitions which I have here given, and to the relations of force and energy which I have expressed, appear to be metaphysical rather than physical. At all events, I think he has offered no physical objection. If that be the case, I can only say that his objections do not appeal to my mind in opposition to the logic of facts. (Cheers.)

The meeting was then adjourned.