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DAY-BREAK.

From a painting by —. Tracey.

DAYBREAK.

A wind came up out of the sea
And said, "O mists, make room for me!"

It hailed the ships, and cried, "Sail on,
Ye mariners, the night is gone."

And hurried landward far away,
Crying, "Awake! it is the day."

It said unto the forest, "Shout!
Hang all your leafy banners out!"

It touched the wood-bird's folded wing,
And said, "O bird, awake and sing!"

And o'er the farms, "O chanticleer,
Your clarion blow; the day is near!"

It whispered to the fields of corn,
"Bow down, and hail the coming morn!"

It shouted through the belfry-tower,
"Awake, O bell! proclaim the hour."

It crossed the churchyard with a sigh,
And said, "Not yet! in quiet lie."

H. W. LONGFELLOW.

(5) CENTRIFUGAL FORCE & GRAVITATION.

THEORY OF THE NATURE OF LIGHT.

THE WAVE THEORY OF SOUND

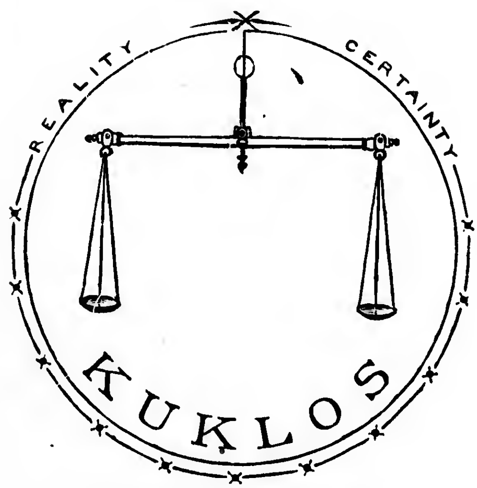
THE NATURE OF FORCE,

AND

THE MANIFESTATION OF FORCE IN THE PHENOMENA BELONGING TO PHYSICAL SCIENCE.

BY

JOHN HARRIS.



Montreal:
PRINTED BY LOVELL PRINTING AND PUBLISHING CO.
ST. NICHOLAS STREET.

JUNE, 1875.

PREFATORY NOTE.

The particular subject of this book is the true nature, in a physical sense, of Light, and an examination of certain doctrines now taught in respect to it. The doctrine, now almost universally considered as authorized by science, known as the Undulatory Theory of Light is closely allied to the Wave Theory of Sound, upon the analogy to which, indeed, it is in a considerable measure based and supported. A part of the objections which we have to offer to the Undulatory Theory apply also to the Wave Theory of Sound, and it appears therefore desirable to put before the reader a brief examination of that important theory also. In order to do this without complicating the immediate argument on the subject of Light, the examination of the Wave Theory and observations on the nature of Sound will appear as a second division of this book, in which division we purpose also to supply certain facts from the record of Physical Science illustrating the arguments and conclusions on the subjects of Light and Sound in their relation to Physical Science.

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FIRST DIVISION.

The Nature of Light.

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DARKNESS AND LIGHT.

Hail, holy Light, offspring of Heaven first-born!
Or of the Eternal, co-eternal beam
May I express thee unblamed? since God is light,
And never but in unapproachèd light
Dwelt from eternity, dwelt then in thee,
Bright effluence of bright essence increate.
Or were'st thou rather pure ethereal stream.
Whose fountain who shall tell? before the sun,
Before the heavens, thou wert, and at the voice
Of God, as with a mantle, didst invest
The rising world of waters dark and deep
Won from the void and formless infinite.
Thee I revisit now with bolder wing,
Escaped the Stygian pool, though long detained
In that obscure sojourn, while in my flight
Through utter and through middle darkness borne
With other notes than to the Orphean lyre,
I sung of Chaos and eternal Night,
Taught by the heavenly Muse to venture down
The dark descent, and up to reascend,
Though hard and rare: thee I revisit safe,
And feel thy sovereign vital lamp; but thou
Revisitest not these eyes, that roll in vain
To find thy piercing ray, and find no dawn;
So thick a drop serene hath quenched their orbs,
Or dim suffusion veiled. Yet not the more
Cease I to wander where the Muses haunt
Clear spring, or shady grove, or sunny hill,
Smit with the love of sacred song; but chief
Thee, Sion, and the flowing brooks beneath,
That wash thy hallowed feet, and warbling flow,
Nightly I visit: nor sometimes forget
Those other two equalled with me in fate,
So were I equalled with them in renown,
Blind Thamyris and blind Mæonides,
And Tiresias and Phineus, prophets old:
Then feed on thoughts that voluntary move
Harmonious numbers; as the wakeful bird
Sings darkling, and in shadiest covert hid
Tunes her nocturnal note. Thus with the year
Seasons return, but not to me returns
Day; or the sweet approach of even or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks, or herds, or human face divine;
But cloud, instead, and ever-during dark,
Surrounds me; from the cheerful ways of men
Cut off, and for the book of knowledge fair
Presented with a universal blank
Of nature's works, to me expunged and rased,
And wisdom at one entrance quite shut out;
So much the rather thou, celestial Light,
Shine inward, and the mind through all her powers
Irradiate; there plant eyes, all mist from thence
Purge and disperse, that I may see and tell
Of things invisible to mortal sight.

JOHN MILTON.

THE NATURE OF LIGHT.

That which maketh manifest is light.

(1.) *The Corpuscular Emission Theory.*

A theoretical explanation of the observed phenomena belonging to the subject of light, proposed by Sir Isaac Newton, is known as Newton's emission theory, or as it is sometimes called, the corpuscular theory of light.

The following is the statement of the most important propositions contained in it:

From *Lardner's Natural Philosophy.*

1222. "*Corpuscular Theory.*—In the corpuscular theory, which was adopted by Newton as the basis of his optical enquiries, light is considered as a material substance, consisting of infinitely minute molecules which issue from luminous bodies and pass through space with prodigious velocities. Thus, in this hypothesis, the sun is regarded as a source from which such molecules or corpuscles proceed in every direction, with such a velocity that they pass from that luminary to the earth, over a distance of ninety-five millions of miles in about eight minutes and thirteen seconds.

This immense velocity with which they are endued, amounting to nearly two hundred thousand miles per second, united with the fact established by observation, that they do not impress with the slightest momentum the "lightest objects which they strike, render it necessary to suppose that they are so minute as to be altogether destitute of inertia or gravity. The strongest beam of sunlight acting upon the most delicate substance, upon the fibres of silk or the web of the spider, or upon gold leaf, does not impress upon them the slightest perceptible motion. Now, in order that a particle of matter, endued with a velocity so great, should have no perceptible momentum, it is necessary to suppose it to be almost infinitely minute.

But this minuteness requires to be admitted to a still greater extent; when it is considered that particle after particle, striking upon bodies so light, even after the communication of their forces, impart to them no perceptible motion.

1223. "*Difference of colour explained.*—In this system the difference of colour which prevails among the different homogeneous lights, the combination of which constitutes solar light, is ascribed to different velocities.

Thus the sensation of red is produced by luminous molecules animated by one velocity, orange by another, blue by another, and so on."

1224. "*Laws of refraction and reflection explained.*—The law which renders the angle of reflection equal to the angle of incidence, is explained by supposing such molecules to have perfect elasticity. The law of refraction is explained by supposing that such molecules are subject to an attraction towards the perpendicular when they enter a denser, and by a repulsion from it when they enter a rarer medium."

Objections to the Corpuscular Theory.

Taking the statement of the theory just quoted. "In the corpuscular theory, which was adopted by Newton as the basis of his enquiries, light is considered as a material substance, consisting of infinitely minute molecules which issue from luminous bodies and pass through space with prodigious velocities." It necessarily follows, as a corollary, that when the sun has continued to shine for any length of time on a body which absorbs the light, a certain appreciable amount of the material projected from the sun, as light, will remain in that body, by which the gravity and mass of the body will be increased. Now if this actually happened it could not long remain unnoticed. Lardner himself remarks, in reference to the hypothetical particles which, according to the theory, issue from luminous bodies, it is necessary to suppose that they are so minute as to be altogether destitute of inertia or gravity. "The strongest beam of sunlight acting upon the most delicate substance, upon the fibres of silk, or the web of the spider, or upon gold-leaf, does not impress upon them the slightest perceptible motion. Now, in order that a particle of matter endued with a velocity so great should have no perceptible momentum, it is necessary to suppose it to be almost infinitely minute." It is evident that Dr. Lardner, in writing this, must have been misled by the theory itself and the authority of Newton into stating a supposition which it is not scientifically permissible to entertain. By the expression particles almost infinitely minute is meant particles extremely small, *i. e.*, particles of very small size. But the gravity of a material substance, whatever its size may be, cannot be got rid of by dividing and sub-dividing it into very small or into extremely minute parts; its gravity cannot in such a manner be even lessened. The sum of the gravities of the very small, or of the extremely minute parts will exactly make up the gravity which the entire body possessed, previously to its division. Take, for instance, a pound by weight of any substance, and suppose it to be divided into a million parts, each of the parts being exactly similar and of the same size; then, each of those parts will weigh the one millionth of a pound, and, if one of them were to be again divided into a thousand parts, then one of those products of the sub-division would weigh the one thousandth of the millionth of a pound. The last particles would be very small, but nevertheless, if a thousand millions of them were projected by the sun in the course of an hour on to any one particular spot, a quantity of the material amounting to a pound in weight thereof would be the aggregate product at the end of that time. And again, how is matter, whether the particles be large or small, to move with an enormous velocity without having or acquiring momentum? *Gravity*, when motionless, [*i. e.*, when restrained from moving] and *momentum*, when in motion, are two of the characteristic properties of *matter*, by which is meant *some material thing* whether it be an aggregated mass of enormous bulk, such as the planet Jupiter, or the most minute particle that can be imagined. Dr. Lardner also states that: "The law of refraction is explained by supposing that such molecules are subject to an attraction towards the perpendicular when they enter a denser, and by a repulsion from it when they enter a rarer medium." Now this is no explanation in a scientific sense; so far from it, such a supposition is inadmissible unless supported by some proof or evidence outside the theory. There is no support in this case, but on the contrary the suggestion is quite gratuitous and altogether improbable. Why should a molecule of matter be attracted by a perpendicular to a denser, or be repelled by a perpendicular to a rarer, medium ?

It has been long since established as a fact, by the results of numerous careful experiments and observation, that a ray of light, on entering a denser from a rarer medium is refracted towards a perpendicular to the surface at which it enters, and, on entering a rarer from a denser medium, is refracted from a perpendicular to the surface of the rarer medium, at which it enters. When asked to give a reason, it is scientifically correct to say in reply that it is according to, or in obedience to, the law of the refraction of light, which is recognized as an established law belonging to the science of Optics, because demonstrated by the observed facts, of which, or from which, it may be said to be a generalization. But when we wish to proceed further, and to explain the particular nature and properties of the ray of light which is so refracted, and to refer the law of the refraction of light to a more general or primary law, and thus to explain *particularly* the cause of the ray being refracted according to the law, it will not then be in accordance with the rules of sound science to invent a cause expressly for the purpose of the explanation; namely, to suppose a unique cause unsupported by experimental evidence or by analogy; such, for example, as a force elsewhere unknown or unrecognized, or a known force as acting in a manner unprecedented and elsewhere unobserved. To do this would be not to explain, but to build up prejudice in the way of scientific explanation. If more sound and certain knowledge cannot be obtained on a particular subject, it is unadvisable to dilute with uncertain, and worse than useless to vitiate with false and unsound knowledge, that which we do already possess.

(2.) *The Undulatory Theory.*

In consequence of the corpuscular emission theory being found insufficient to satisfactorily explain some of the more recently observed phenomena of light, belonging in particular to what is termed *interference*, it has been generally given up, and, in its place, the undulatory theory of light has been adopted as the recognized basis of optical science. The undulatory theory is of almost the same age as the emission theory of Newton, having been first proposed and adopted by Hooke and Huygens, contemporaries of Newton; it is only, however, since the commencement of the present century that this theory has been more completely developed, and still more recently that it has been generally (now, almost unanimously) adopted. This theory is also sometimes called the wave-theory of light, and it has been primarily derived from what is known as the wave-theory of sound*, light being considered as the effect of an undulation or agitation propagated through and by means of the particles of a subtle and extremely elastic fluid called *ether;* analagous to the effect of the wave agitations of the particles of air, or other gaseous fluid, which according to the wave-theory is recognized as causing the effect, or class of effects, denominated sound.

Lardner's Natural Philosophy.

1225. "*Undulatory Theory.*—In the undulatory theory which was adopted by Huygens, and after him by most continental philosophers, light is regarded as in all respects analagous to sound.

"The luminous body in this system does not transmit any matter through space any more than a bell transmits matter when it sounds. The luminous body is regarded as a centre of vibration; but in order to explain the transmission of this vibration through space, the existence of a subtle fluid is assumed, which plays, with regard to light, nearly the same part as the atmosphere plays with regard to sound. The sun, in this theory, then, is a centre of vibration, and the space which surrounds him being filled with an atmosphere of this subtle fluid, transmits this vibration exactly as the atmosphere transmits the vibration of a sounding body."

1226. "*The Luminous Ether.*—This hypothetical fluid has received the name of *ether*. It is supposed not only to fill all the vacant spaces of the universe which are unoccupied by bodies, but also to fill the interstices which exist between the component parts of bodies. Thus it is not only mingled with the atmosphere which surrounds the earth, but also with the component parts of water, glass, and all transparent substances; and since opaque substances, when rendered sufficiently thin, are penetrable more or less by light, it is necessary to admit that it also fills the pores of such bodies. If this luminous ether did not prevail throughout the whole extent of the atmosphere, the light of the stars could not reach our eyes. If it did not exist in water, glass, precious stones, and all transparent substances, these substances could not be penetrable by light as they are; in fine, if it did not exist in the humours of the eye, light could not affect this organ, and the undulations could not reach the membrane of the retina."

1227. "*Effects ascribed to its varying density.*—But although this luminous ether is thus assumed to be omnipresent, it does not everywhere prevail with the same density. It is probable that its density in the celestial spaces which intervene between planet and planet is the "same which it has under the exhausted receiver of an air-pump or above the mercurial column in a barometer.

But its density in transparent media must be different, because to explain the phenomena of light passing through them it is necessary to suppose that the undulations change their magnitude, a supposition which is only compatible with a change in the elasticity of the ether. We shall see further, that in some transparent bodies existing in a crystallized state it is necessary to suppose also that the density of the ether in different directions in the same medium varies.

If this universal ether were for a moment in a state of perfect repose, the universe would be in absolute darkness; but the moment its equilibrium is disturbed, and that an undulation or vibration is imparted to it, that instant light is created, and is propagated indefinitely on all sides, as, in an atmosphere perfectly tranquil, the vibration of a musical string or the sound of a blow is propagated to a distance in all directions according to determinate laws.

Light itself, must not, however, be confounded with the ether which is the medium of its propagation. Light is no more identical with the hypothetical ether than sound is identical with air. The ether, in the one case, and the air in the other, are merely the media by which the systems of undulations which constitute the real sense of light and sound are propagated."

1228. "*Analogy of light and sound.*—In considering the analogy between light and sound, however, there is an important distinction which must not escape notice. Sound is propagated, not only by undulations transmitted through the air, but also by undulations transmitted through other fluids as well as solids, as has been already explained. Light, however, according to the undulatory theory, is transmitted only by the undulations of the luminous ether. Light, therefore, does not pass through a transparent body, such as glass, in the same manner as sound is transmitted through the same body. The undulations by which sound is propagated through the air would be imparted to glass itself, which will continue them and transmit them to another portion of air, and thence to the ear; but when the undulations of light are transmitted through glass or any other transparent medium, they must be supposed to be propagated, not by the vibration of the glass itself, but by the vibration of the subtle ether which pervades its pores."

Objections to the Undulatory Theory.

The Ether.—The supposed fluid thus named is usually spoken of by writers on optics as a hypothetical fluid; but such a use of the expression 'hypothetical' is apt to mislead... if the writer, who so uses the word, supposes at the same time that the undulatory theory of light is scientifically established. If the expression 'hypothetical' is merely intended to indicate that the supposed subtle fluid, the ether, cannot be directly taken cognizance of by the senses, its use is objectionable; because many natural as well as all ideal facts are in the same case..that is, they cannot be directly cognized by the senses. A belief that the undulatory theory of light is scientifically established, should include the belief that the existence of the ether is demonstrated by the observed facts and the legitimate reasoning belonging to that theory. If the *non-existence* of the ether fluid were to be demonstrated, the undulatory theory of light, which is based upon its assumed existence, would necessarily have to be given up; and therefore if, or so long as, the existence of the ether is in any degree doubtful, so long must the theory itself be in doubt, and must not be considered as scientifically established—merely a theory, not a demonstrated theorem. The expression 'subsensible' as applied by Prof. Tyndall to the (supposed) ether fluid is much preferable to 'hypothetical,' *if* the theory *is accepted* as demonstrated. In Dr. Lardner's statement of the undulatory theory, quoted at page 3, a concise explanation of the supposed nature of the luminous ether will be found. Also in Prof. Tyndall's lecture on light, (*See Appendix*,) wherein the sound and light-waves are compared, the material and gaseous nature of the subsensible fluid is very distinctly assumed: "Could you see the air through which sound-waves are passing, you would observe every individual particle of air oscillating to and fro." "Could you see the ether, you would also find every individual particle making a small excursion to and fro." The general object of this part of the lecture is to show the analogy between light and sound; but we can scarcely be incorrect in supposing that the more particular object is to demonstrate the existence of the subsensible ether-fluid by thus showing and illustrating the analogy.

A difficulty of a kind to make extreme caution necessary as to accepting the existence of the ether, until strictly demonstrated, is that the theory and the observed facts belonging to it together necessitate the assumption that the material subsensible fluid occupies all space, and that all other descriptions of matter, not absolutely opaque, must be considered porous, and as having their interior spaces all filled with ether. It appears that this undulatory theory of light became the subject of a conversation between Prof. Tyndall and Sir David Brewster, and that the latter stated his opinion as to the existence of the ether-fluid in the following words: "That his chief objection to the undulatory theory of light was that he could not think the Creator guilty of so clumsy a contrivance as the filling of (*? all*) space with ether in order to produce light." On which observation Prof. Tyndall, in his published lecture, page 40, makes this remark: "This, I may say, is very dangerous ground; and the quarrel of science with Sir David, on this point, as with many other persons on other points, is, that they profess to know too much about the mind of the Creator." These observations bring a subject directly under consideration distinct from and of greater importance than the undulatory or other physical theory of light, and as it is also the subject to which, as stated in our introductory remarks, the more general purpose of our work is directed, we shall include in our notice of them an examination of their significance in reference to that more important subject.

The subject thus brought particularly under consideration is the relation of science, or what is now considered as science, to the facts of creation and to the Creator Himself, and therefore to theology. It may be said that the observations were not particularly intended to be applied in this sense, but they are made public, and they define in a measure the position occupied at the present time by science, in this relation, according to the judgment of the speakers.

The observation of Sir David Brewster was certainly blameworthy as being expressed in irreverent language. An observation made in such terms under any circumstances cannot be reasonably regarded otherwise than as foolish and wrong; but if made deliberately and guardedly on a grave and important subject of science... and published . . . an observation so expressed must be considered blameworthy in a much higher degree. It should be remarked, however, on behalf of Sir David, that, in this case, his observation was probably in its form a careless off-hand expression of opinion not intended for the public. Apart from the very reprehensible form of the expression, the meaning of the objection, which Sir David may be understood as intending to convey, does not appear to us by any means unreasonable. The supposition of all space being filled with a material fluid for the purpose of producing effects at certain distant points, or in other words an omnipresent material fluid filling and pervading the universe for the production of one class or kind of effect only, does not seem to harmonize with what we do know of the Creator's work but, on the contrary, it presents itself to the educated mind as a contrast to the directness and simplicity of the methods employed in other parts of creation. Notwithstanding the supposed attenuated subsensible characteristics of the fluid, the inconceivably enormous quantity of material required by the theory at once suggests improbability. If, however, the objection went no further than this, it might perhaps be answered with some degree of force by supposing that the ether fulfilled other important purpose or purposes with which we are as yet altogether unacquainted, but the objection does go much further, because the ether fluid is, by the assumption, material, and upon this assumption the theory rests. Why, then, does not the ether, in obedience to the general law known to govern, and recognized as universally governing, matter, collect around the centres of gravitating influence? Are we asked to suppose the ether to differ from all other varieties of matter, to be exempt from the influence of gravitation and at the same time to have other properties in common with the other descriptions, and to be controlled by some of the laws governing other kinds, of matter; as, for example, to possess the property of elasticity, and to be capable of propagating an impulse by undulations of its particles? To admit such a proposition even as an assumption is extremely dangerous. It is to take leave of all certainty; to bid farewell to science, and to set sail without rudder or compass on the dark and treacherous ocean of metaphysics. Very much of the sound natural science now possessed by us is based on the certain knowledge that *gravitation* is a general law governing all matter. If this is uncertain, or is to be considered uncertain and open to controversy, where, then, are we to find scientific certainty in respect to the material world? If any one variety of matter may be exempt from such a general law, so also may other varieties. If the reply to this should be . . well, then, the ether in that sense is not material; it is evident that the undulatory theory of light must at once fall to the ground, because it rests upon the assumption that the ether is a material fluid, possessing (some of) the properties belonging essentially and distinctively to all matter.

Prof. Tyndall does not, however, make any direct reply to the objection of Sir David Brewster, but thereupon makes a statement in the name of science, against which statement we feel obliged, also in the name of science, to protest. The statement or remark is perhaps not quite so definite as to preclude the possibility of misapprehension as to its full meaning; but we are afraid that the meaning which it will be generally understood to convey is that the mind of the Creator, as displayed in, and made known to us by and through, the facts of creation, is not the proper and legitimate subject for science to occupy itself about. Moreover, a meaning may be understood to be indirectly included to the effect that the 'reason' or 'reasonableness' of the Creator is different *in kind* from the 'reason' or 'reasonableness' of human science. Now, assuming that either or both of these meanings are to be understood, we have to state directly to the contrary, that the express object and purpose of science, in any high sense, is to obtain knowledge, a better and more perfect knowledge, and always more knowledge of the mind of the Creator; and that having obtained such knowledge, the legitimate and best employment of those who have acquired such knowledge is in teaching and making known the mind of the Creator for the guidance of those who have not the opportunity to seek this higher kind of knowledge for themselves.

In reference to the (inferential) secondary meaning mentioned above, we would say that, if we had not an assured belief as to human reason (*terrestrial reason*) being in harmony with, based upon, and the same *in kind* as the Reason of the Creator (*celestial reason*), science, in any higher sense, would lose its interest for us. A merely human science—which is not a part of universal science, and which, so far as any one man is concerned, is confined to the few years of a man's terrestrial existence—does not appear to us a very desirable or interesting pursuit, merely for its own sake. A man crammed full of scientific knowledge is not, therefore, necessarily, in a merely terrestrial sense, happier than a man who possesses very little, nor is he likely to be physically stronger or better developed in consequence. Prof. Tyndall highly values scientific knowledge, so do we; he also expresses a sort of compassion for those who do not know, and a certain degree of contempt for those who contemn, science in the higher sense—and which feeling we also share; but it is *because* we believe that in acquiring scientific knowledge we are acquiring, and in communicating scientific knowledge we are communicating, that which belongs, not merely to a brief terrestrial, but, also, to a higher state of existence, and which may be considered as belonging to, and forming a part of, immortality. If we did not so believe, we should incline to the opinion that the practical-sense men who say 'cui bono' when invited to engage in scientific pursuits, and who can see no use in science except as a means, or as furnishing the means of ameliorating the hardships of human existence and of increasing the amount of sensual ease and enjoyment—the practical sense and common-sense men, who so argue, would in that case, as we opine, have much the strongest argument; for other purpose or in other sense—for its own sake, for instance, meaning thereby the gratification supposed to arise from feeling more highly cultured or more intellectually developed than others, the man ardently devoted to the acquisition of scientific knowledge may be justly considered as on a par with, or, at least, not much better than, the man devoted to the acquisition and accumulation of material wealth. For where, in such a sense, is the difference? In either case it is the selfish endeavour to acquire the possession of wealth for its own sake.. *i.e.*, for the gratification of a desire to be richer than his fellows.

If the reply to this should be...That is not what we mean or understand by studying science for its own sake.

The man who in the higher sense devotes himself to the acquisition and promotion of scientific knowledge does so unselfishly; he knows that he can live for a few years only and enjoy for a short time only a very partial possession of the knowledge he thus acquires, but he believes that he is assisting to build up that which will endure permanently and, by elevating their condition and increasing their intellectual happiness, will benefit his successors for untold ages. Yes..but if this is the meaning, it must in reason be based upon the belief that human science is in harmony with, belongs to, and is a part of celestial science, and that, therefore, the express object of human science is, by persistent endeavour and effort, to make sure that it belongs to the Mind of the Creator and to learn more of that Mind: for, otherwise, there can be no assurance of permanence, nor can there be any assurance, even, that the value of such science is anything more than suppositious, since it may be in a celestial sense, false. Moreover, is the man sure that he will live and possess the knowledge which he has acquired, for a few years only?...does he usually work in that belief? Where is the man of science who cares nothing about the posthumous credit of an important discovery which he has made, or is quite careless as to whether his reputation will endure and his name be held in honour and respect by succeeding generations?

The objection which we have just stated, in the foregoing amplification of Sir David Brewster's objection, *viz.*, to the assumption of ether as a form of matter exempt from the influence of gravitation, appears to us to be, of itself, altogether fatal to the undulatory theory of light, and to render the acceptance of that theory scientifically inadmissible; but even if the supposition were to be entertained that this objection might be, in some way or other, surmounted, and the actual existence of the ether shown to be theoretically possible, there would yet remain, at least one serious difficulty which has been, as it seems to us, put aside, rather than dealt with and surmounted by the supporters of the theory. We allude to the kindred phenomena of radiant heat. The nature of this particular difficulty may be thus briefly stated:—the phenomena of light and of radiant heat are so analogous, so evidently allied and similar to each other, in many respects, that it is almost, if not quite, impossible in a reasonable sense to suppose the one effect (or class of effects) to result from the undulation of an elastic material fluid and not to suppose the other effect (or class of effects) to be produced in the like manner; but although there are very close analogies between the two kinds of effect (or classes of phenomena) in some respects, there are also differences of an essential and distinctive character, such that we should feel at least a very grave difficulty as to admitting even a theoretical supposition that a mere variation in the velocities of the undulations of the same fluid can occasion them. We say that the difference in the characteristics of light and radiant heat are too great, and of essentially too distinctive a kind, to allow the supposition that a certain number of undulations, or vibratory pulses of ether, taking place in a second of time may produce light, and that a certain lesser (or greater) number of vibratory pulses, in a second, may be productive of radiant heat. What is the alternative? To suppose the existence of two different omnipresent ethers?

Before leaving for the present the important question as to the position which science, in its higher signification, does or ought to occupy, we will make some remarks as to the meaning which correctly belongs to the term metaphysics, in its relation to science. The indefiniteness which constitutes one of the leading characteristics of metaphysics, attaches in some degree even to the name or expression by which it is denoted, in such wise that probably no two scientifically educated persons could be found at the present time to agree as to what ought or ought not to be included in a strict sense under that title.

To make our remarks as brief and subjective as the nature of the subject will permit, we will give here one example of the confusion of thought, and inferential mystification instead of increased knowledge, which results from that indefiniteness.

In the work of Sir John Herschel, *Outlines of Astronomy*, from which we have made many quotations, we find a note, at the foot of page 212 as follows: "This condition is indispensable. Without it we fall into all those difficulties which M. Doppler has so well pointed out in his paper on aberration. (Abhandlungen der k. boemischen Gesellschaft der Wissenschaften. Folge V. vol. iii.) If light itself, or the luminiferous ether, be corporeal, the condition insisted on amounts to a formal surrender of the dogma, either of the extension or of the impenetrability of matter; at least in the sense in which those terms have been hitherto used by metaphysicians. At the point to which science is arrived, probably few will be found to maintain either the one or the other."

The indispensable condition referred to is stated in the text above. "In whatever manner we consider light, whether as an advancing wave in a motionless ether, or a shower of atoms traversing space, (provided that in both cases we regard it as absolutely incapable of suffering resistance or corporeal obstruction from the particles of transparent media traversed by it.)" The words within the brackets expressing the condition insisted upon.

The doctrine of the impenetrability of matter is thus stated by *Lardner*, in his *Natural Philosophy.**

(22) "*All matter impenetrable.*—Impenetrability is the quality in virtue of which a body occupies a certain space, to the exclusion of all other bodies. This idea is so inseparable from matter, that some writers affirm that it is nothing but matter itself; that is, that when we say that a body is impenetrable, we merely say that it is a body.

However this be, the existence of this quality of impenetrability is so evident as to admit of no other proof than an appeal to the senses and the understanding. No one can conceive two globes of lead, each a foot in diameter, to occupy precisely the same place at the same time. Such a statement would imply an absurdity, manifest to every understanding."

23. "*Gaseous bodies impenetrable.*—Even bodies in the gaseous form, the most attenuated state in which matter can exist, possess this quality of impenetrability as positively as the most hard and dense substances."

Now this doctrine, or teaching, as to one of the recognized properties of matter, is, if we understand Herschel's

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*Extension is not distinguished by Lardner as one of the properties of matter; probably he considered it synonymous with magnitude, or perhaps, as merely expressing the existence and natural reality of matter.

remarks aright, considered by him to be a metaphysical dogma, and no longer tenable in a strictly scientific sense; and, moreover, he supposes, it would seem, there are now but few persons of scientific education who think differently.

Two distinct questions are herein involved, both of them of much importance. The one is, whether that science, which has and professes a definite belief in the existence of matter, such as defined by Lardner, is sound science or the reverse. The other question is, the correct use of the expression 'metaphysics.' It is with respect to the last of these questions that we think it desirable to make here a few observations. The particular word 'metaphysics' may, of course, be used, as any word in nomenclature may be used, in whatever sense it may be generally agreed to use and understand it. But the important question here at issue is, (1st)—Whether all knowledge, all that is supposed to be, or goes by the name of, knowledge, of every kind and description, if only it be classified and systemized, is to be called and considered 'science;' or, (2nd)—Whether it is necessary there should be a distinction and separation of the certain and sound knowledge, from the uncertain and unsound.

Now the necessity of a division has been for a long time past generally recognized; for instance, that description of classified knowledge which at an earlier period was admitted and highly reputed under the title 'astrology' and which, since the time of Francis Bacon, has ceased to be considered a part of the classified knowledge belonging to science. If, therefore, it is right and proper to have a division and to have an expression 'science,' to denote collectively all the descriptions of knowledge considered beneficial and to be worth preserving and cultivating, it is likewise desirable to have a general expression to denote collectively those descriptions of knowledge, systematically classified or otherwise, which are of the opposite character from the former—that is, which are, or ought to be, under a strictly correct division, excluded from science. It is in this sense that we understand and purpose to use the expression 'metaphysics,' because certain classified descriptions of knowledge which ought, according to our judgment, to be excluded from science, are already particularly denoted by that expression, and, moreover, the indefinite and mystical meaning which the expression suggests to the generality of people, makes it the more suitable as a collective expression for all kinds of knowledge which are indefinite, uncertain and unsound.

The mode of its use by Sir John Herschel, in the preceding quotation is, therefore, according to our view, an inversion of the correct or desirable application of the term, 'metaphysics;' for, therein it is used to denote the *definite* teaching—*i e.*, the recognition and intelligible definition of the natural reality; and, by inference, the expression 'science' may be understood to apply to the *indefinite* teaching—viz, to that which is indefinite and unintelligible.

We find in Prof. Tyndall's *Lectures on Light*,* *page* 55, the indirect statement of, what appears to us to constitute, another difficulty in the way of accepting the undulatory theory. That statement reads: " All space

* See quotation in the Appendix.

is filled with matter oscillating at such rates. From every star waves of these dimensions move with the velocity of light, like spherical shells, outwards. And in the ether, just as in the water, the motion of every particle is the algebraic sum of all the separate motions imparted to it. Still, one motion does not blot the other out; or, if extinction occur at one point, it is atoned for at some other point. Every star declares by its light its undamaged individuality, as if it alone sends its thrills through space."

It is an observed fact and unquestionably true that every star does so declare its undamaged individuality; but how can these undulations, which are defined by the theory to be of the nature of waves or of progressive oscillations resulting from motion in the particles of a material fluid . . . we ask, how can these undulations reach us in innumerable quantity at the same time and from every direction, and yet not damage, modify, interrupt, or, in any way, interfere with each other? It is not only from every star and every luminous body that these undulations have to reach the eye in undamaged individuality, but, if we apprehend the explanations of the theory aright, also from every visible object. At the rate of only one undulation in a second it would be embarrassing even to imagine these undulations crossing each other in every direction without mutual interruption, but what is the estimate of the number by those who support the theory? "All these waves enter the eye, and hit the retina at the back of the eye, in one second. The number of shocks per second necessary to the production of the impression of red is, therefore, four hundred and fifty one millions of millions. In a similar manner, it may be found that the number of shocks corresponding to the impression of violet is seven hundred and eighty-nine millions of millions. All space is filled with matter oscillating at such rates." *

We do not find any explanation of this difficulty even attempted; an occasional or possible interference is alluded to by the remark that "if extinction occurs at one point, it is atoned for at some other point;" but, with the various effects, classed as the phenomena of interference and belonging to Optics and Acoustics respectively, in mind, we feel only that this last remark increases our inability to accept the proposition by making the impossibility of reconciling the theory with the known facts of science still more apparent.

(3.) *Velocity of Light theory.*

Both of these theories, the corpuscular, and undulatory theories of light, which have been successively accepted and adopted as forming a part of optical science, have one primary basis in common, namely, the velocity of light, which is assumed to have been antecedently established as an observed fact.

Since we have objected, for reasons more or less fully stated, to the acceptance of either of these theories as belonging to sound science in the sense of demonstrated theorems, we propose now to examine the evidence as to that alleged velocity of light which is assumed to have been antecedently established.

The history of this (assumed) discovery or observation, we find from the general record to be briefly as follows:

* Lectures on Light, page 55. (See quotation in the Appendix.)

Lardner's Astronomy.

(2959). "*Motion of light discovered and its velocity measured.*—Soon after the invention of the telescope, Roemer, an eminent Danish astronomer, engaged in a series of observations, the object of which was the discovery of the exact time of the revolution of one of these bodies around Jupiter. The mode in which he proposed to investigate this was by observing the successive eclipses of the satellite, and noticing the time between them.

Now if it were possible to observe accurately the moment at which the satellite would, after each revolution, either enter the shadow or emerge from it, the interval of time between these events would enable us to calculate exactly the velocity and motion of the satellite. It was, then, in this manner that Roemer proposed to ascertain the motion of the satellite. But, in order to obtain this estimate with the greatest possible precision, he proposed to continue his observations for several months.

Let us, then, suppose that we have observed the time which has elapsed between two successive eclipses, and that this time is, for example, forty-three hours. We ought to expect that the eclipse would recur after the lapse of every successive period of forty-three hours.

Imagine, then, a table to be computed in which we shall calculate and register before hand the moment at which every successive eclipse of the satellite for twelve months to come shall occur, and let us conceive that the earth is at *A*, at the commencement of our observations; we shall then, as Roemer did, observe the moment at which the eclipses occur, and compare them with the moments registered in the table.

Let the earth, at the commencement of these observations, be supposed at *E*. fig. 756, where it is nearest to

"Jupiter. When the earth has moved to *E*," it will be found that the occurrence of the eclipse is *a little later* than the time registered in the table. As the earth moves, from *E*."

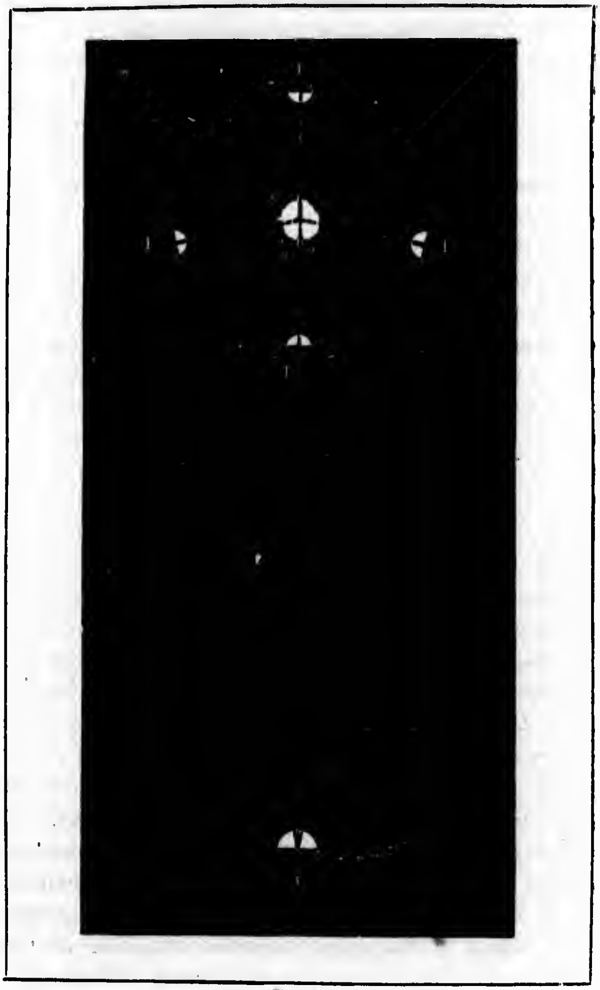

Fig. 756.

"towards *E.'''*, the actual occurrence of the eclipse is more and more retarded beyond the computed occurrence, until at *E.'''* in conjunction, it is found to occur about sixteen minutes later than the calculated time."

"By observations such as these, Roemer was struck with the fact that his predictions of the eclipses proved in every case to be wrong. It would at first occur to him that this discrepancy might arise from some errors of his observations; but, if such were the case, it might be expected that the result would betray that kind of irregularity which is always the character of such errors. Thus, it would be expected that the predicted time would sometimes be later, and sometimes earlier, than the observed time, and that it would be later and earlier to an irregular extent. On the contrary, it was observed, that while the earth moved from *E.* to *E.'''*, the observed time was continually later than the predicted time, and moreover, that the interval by which it was later continually and regularly increased. This was an effect, then, too regular and consistent to be supposed to arise from the casual errors of observation, it must have its origin in some physical cause of a regular kind. The attention of Roemer being thus attracted to the question, he determined to pursue the investigation by continuing to observe the eclipses. Time accordingly rolled on, and the earth, transporting the astronomer with it, moved from *E.'''* to E.' It was now found, that though the time observed was later than the computed time, it was not so much so as at *E.'''*, and, as the earth again approached opposition, the difference became less and less, until, on arriving at *E.*, the position of opposition, the observed eclipse agreed in time exactly with the computation. From this course of observation it became apparent that the lateness of the eclipse depended altogether on the increased distance of the earth from Jupiter. The greater that distance, the later was the occurrence of the eclipse as apparent to the observers, and on calculating the change of distance, it was found that the delay of the eclipse was exactly proportional to the increase of the earth's distance from the place where the eclipse occurred. Thus, when the earth was at $E.'''$ the eclipse was observed sixteen minutes, or about 1000 seconds, later than when the earth was at E. The diameter of the orbit of the earth $E. E.'''$ measuring about two hundred millions of miles, it appeared that that distance produced a delay of a thousand seconds, which was at the rate of two hundred thousand miles per second. It appeared, then, that for every two hundred thousand miles that the earth's distance from Jupiter was increased, the observation of the eclipse was delayed one second.

Such were the facts which presented themselves to Roemer. How were they to be explained? It would be absurd to suppose that the actual occurrence of the eclipse was delayed by the increased distance of the earth from Jupiter. These phenomena depend only on the motion of the satellite and the position of Jupiter's shadow, and have nothing to do with, and can have no dependence on, the position or motion of the earth, yet unquestionably the time they *appear* to occur to an observer upon the earth, has a dependence on the distance of the earth from Jupiter.

To solve this difficulty, the happy idea occurred to Roemer that the moment at which we see the extinction of the satellite by its entrance into the shadow is not, in any case, the very moment at which that event takes place, but sometime afterward, viz., such an interval as is sufficient for the light, which left the satellite just before its extinction, to reach the eye. Viewing the matter thus, "it will be apparent that the more distant the earth is from the satellite, the longer will be the interval between the extinction of the satellite and the arrival of the last portion of light, which left it, at the earth; but the moment of the extinction of the satellite is that of the commencement of the eclipse, and the moment of the arrival of the light at the earth is the moment the commencement of the eclipse is observed.

Thus Roemer, with the greatest felicity and success, explained the discrepancy between the calculated and the observed times of the eclipses; but he saw that these circumstances placed a great discovery at his hand. In short, it was apparent that light is propagated through space with a certain definite speed, and that the circumstances we have just explained supply the means of measuring that velocity.

We have shown that the eclipse of the satellite is delayed one second more for every two hundred thousand miles that the earth's distance from Jupiter is increased, the reason of which obviously is, that light takes one second to move over that space; hence it is apparent that the velocity of light is at the rate, in round numbers, of two hundred thousand miles per second.

By more exact observation and calculation the velocity is found to be 192,000 miles per second, the time taken in crossing the earth's orbit being 16*m*. 26. 6*s*."

Having herein the history and particular definition of the observed facts upon which the theory of the velocity of light is supposed to be directly based, we will now quote, also from the same work (*Lardner's Astronomy*), the more general explanation of the phenomena belonging to these facts, in order that the whole of the case may be clearly understood.

Eclipses, Transits, and Occultations of the Jovian System.

(2950) "The motions of Jupiter and his satellites, as seen from the earth, exhibit, from time to time, all the effects of interposition. Let *J. J.'* fig. 810, represent

the planet, *J. f. J.'* its conical shadow, *S. S,* the sun, *E.* and *E.'* the positions of the earth when the planet is in quadrature, in which position the shadow *J. f. J.'* is presented with least obliquity to the visual line, and therefore least foreshortened, and most distinctly seen. Let *b. b.' d.' d.* represent the orbit of one of the satellites, the plane of which coincides nearly with that of the planet's

" orbit, and, for the purposes of the present illustration, the latter may be considered as coinciding with the ecliptic without producing sensible error. From *E.* suppose the visual lines *E. J.* and *E. J.'* to be drawn, meeting the path of the satellite at *d.* and *g.*, and *a.'* and *b.'*, and in like manner, let the corresponding visual lines from *E.'* meet it at *d.'* and *g.'*, and at *a.* and *b.* Let *c.* and *c.'* be the points where the path of the satellite crosses the limits of the shadow, and *h.* and h.', the points where it crosses the extreme solar rays, which pass along those limits.

If l express the length Jf of the shadow, d the distance of the planet from the sun in semi-diameters of the planet, and r and r' the semi-diameters of the sun and the planet respectively,

$$\text{we shall have (2917)} \quad l = d \times \frac{r'}{r - r'}$$

$$\text{But } d = 11227 \qquad r = 441000 \qquad r' = 44000$$

$$\text{and therefore } l = 11227 \times \frac{44}{441 - 44} = 1247:$$

that is to say, the length of the shadow is 1247 semi-diameters of the planet. Now, since the distance of the most remote satellite is not so much as 27 semi-diameters of the planet (2760), and since the orbits of the satellites are almost exactly in the plane of the orbit of the planet, it is evident that this will necessarily pass through the shadow, and almost through its axis, every revolution, and the lengths of their paths in the shadow will be very little less than the diameter of the planet.

The fourth satellite, in extremely rare cases, presents an exception to this, passing through opposition without entering the shadow. In general, however, it may be considered that all the satellites in opposition pass through."

(*Note. This last statement about the fourth satellite appears very remarkable in connection with that which pre-*

cedes it, and with the great breadth of the shadow. But if we assume a moderate amount of vertical deviation above and below the orbital plane of the planet's equator, it becomes quite intelligible why the fourth satellite sometimes passes through opposition without entering the shadow.)

(2951) " *Effects of interposition.*—The planet and satellites exhibit, from time to time, four different effects of interposition."

(2952) " 1st. *Eclipses of the satellites.*—These take place when the satellites pass behind the planet. Their entrance into the shadow, called the *immersion*, is marked by their sudden extinction. Their passage out of the shadow, called their *emersion*, is manifested by their being suddenly relighted."

(2953). 2nd. "*Eclipses of the planet by the satellites.*—When the satellites, at the periods of their conjunctions, pass between the lines *S J*, and *S′ J′*, their shadows are projected on the surface of the planet in the same manner as the shadow of the moon is projected on the earth in a solar eclipse, and, in this case, the shadow may be seen moving across the disk of the planet, in a direction parallel to its belts, as a small round and intensely black spot."

(2954). 3rd. " *Occultations of the satellites by the planet.*—When a satellite, passing behind the planet, is between the tangents *E.J.a′.*, and *E.J.b′.*, drawn from the earth, it is concealed from the observer on the earth by the interposition of the body of the planet. It suddenly disappears on one side of the planet's disk, and as suddenly reappears on the other side, having passed over that part of its orbit which is included between the tangents. This phenomena is called an occultation of the satellite."

(2955). " *Transit of the satellites over the planet.*—When a satellite, being between the earth and planet, passes between the tangents *E.J.* and *E′.J′.*, drawn from the earth to the "planet, its disk is projected on that of the planet, and it may be seen passing across, as a small brown spot, brighter or darker than the ground on which it is projected, according as it is projected on a dark or bright belt. The entrance of the satellite upon the disk, and its departure from it, are denominated its *ingress* and *egress*."

(2956). "*All these phenomena manifested at quadrature.*— When the planet is in quadrature, and the shadow therefore presented to the visual ray with least effect of foreshortening, all these several phenomena may be witnessed in the revolution of each satellite.

The earth being at *E.* or *E'.*, the visual line *E.J.* or *E.' J.'* crosses the boundary *x.'* or *x.* of the shadow at a distance *x'. J.'* or *x. J.*, from the planet, which bears the same ratio to its diameter as the distance of Jupiter from the sun bears to the distance of the earth from the sun, as is evident from the figure. But Jupiter's distance from the sun being five times that of the earth, it follows that the distance *x.J.* is five diameters, or ten semi-diameters, of the planet. But since the distance of the first satellite is only six, and that of the second somewhat less than ten, semi-diameters of the planet, it follows that the paths of these two will lie within the distance *x.J.* or *x.'J.'*

The planet being in quadrature 90° behind the sun, the earth will be at *E.* and the entire section *c. c.'* of the shadow, at the distances of the third and fourth satellites (which are 15 and 27 semi-diameters of the planet respectively), will be visible to the west of the planet, so that when these satellites, moving from *b*, as indicated by the arrow, pass through the shadows, their immersion and emersion will be both manifested on the west of the planet, by their sudden disappearance and reappearance on entering and emerging from the shadow at *c.* and *c.'* But the section of the shadow, at the distances at the first and second "satellites, being nearer to the planet than $x.x.'$ will be visible only at its western edge, the planet intercepting the visual ray directed to the eastern edge. The immersion, therefore, of these will be manifested by their sudden disappearance on the west of the planet, at the moment of their immersion; but the view of their emersion will be intercepted by the body of the planet, and they will only reappear after having passed behind the planet.

The third and fourth satellites, after emerging from the shadow at c'. and appearing to be re-lighted, will again be extinguished when they come to the visual ray $E. J. a'$. which touches the planet. The moment of passing this ray is that of the commencement of their occultation by the planet. They will continue invisible until they arrive at the other tangential visual ray $E. J.'b.'$, when they will suddenly reappear to the east of the planet, the occultation ceasing."

"In the cases of the first and second satellites, the commencement of the occultation preceding the termination of the eclipse, it is not perceived, the satellite at the moment of the interpositon of the edge of the planet not having yet emerged from the shadow. In these cases, therefore, the disappearance of the satellite at the commencement of the eclipse, and its reappearance at the termination of the occultation, alone are perceived, the emersion from the shadow being concealed by the occultation, which has already commenced, and the disappearance at the commencement of the occultation being prevented by the eclipse not yet terminated.

When the satellite, proceeding in its orbit, arrives at $h.'$ its shadow falls upon the planet, and is seen from the earth, at E, to move across its disc as a small black spot, while the planet moves from $h.'$ to h.

When the planet arrives at $g.$ it passes the visual ray $E. J.'$ and while it moves from $g.$ to $d.$ its disc is projected "on that of the planet, and a transit takes place, as already described.

Thus, at quadrature, the third and fourth satellites present successively all the phenomena of interposition: 1st, an eclipse of the satellite to the west of the planet shows both immersion and emersion; 2nd, an occultation of the satellite by the planet, the disappearence and reappearance being both manifested; 3rd, the eclipse of the planet by the satellite; and 4th, the transit of the satellite over the planet."

(2957) "*Effects modified at other elongations.*—There is a certain limit, such as *e*, at which the emersion of the third and fourth satellites is intercepted, like that of the first, by the body of the planet. This is determined by the place of the earth from which the visual ray *e. J. c.'* is directed to the eastern edge of the section of the shadow at the planet's distance. Within this limit the phenomena for the third and fourth satellites are altogether similar, to those already explained in the case of the first and second satellites seen from *E.*

"When the earth is between *s.*, and *s'.* no eclipses can be witnessed. Those of the satellites are rendered invisible by the interposition of the planet, and those of the planet by the interposition of the satellites. When the earth is at *e'.'* and *E.'*, the phenomena are similar to those manifested at *e.* and *E.*, but they are exhibited in a different order and direction. The occultation of the satellite precedes its eclipse, and the latter takes place to the east of the planet. In like manner, the transit of the satellite precedes the eclipse of the planet."

Examination of the Record.

In carefully examining the record of the phenomena together with the explanation contained in the foregoing, we particulary note the very positive assumption that "these phenomena depend only on the motion of the satellites and the position of Jupiter's shadow, and *have nothing to do with,* and *can have no dependence on the position or motion of the earth.*" On careful consideration it becomes evident that this assumption is made to apply not only to the actual phenomena but also to the apparent phenomena as viewed from the earth . . . Is the assumption, so applied, wholly supported by the known circumstances belonging to the phenomena?

If we first suppose the earth's place to be at that part of its orbit nearest to Jupiter, and, having there noted the apparent magnitude (angular magnitude) of that planet, we then suppose the earth removed to the opposite extremity of the orbit to the place most distant from Jupiter, and again note the apparent magnitude of that planet, it is manifest that, the distance of the earth from the planet having increased by about 190 million miles, the apparent magnitude of the planet, as seen from the earth, must have decreased proportionally. Has this no particular relation to the phenomena, such as Lardner assumes that it has not?

In the historical and descriptive statement of Roemer's discovery just quoted, it is stated in effect (1) that Roemer's computation of the times when the commencement of each eclipse was to be expected was made by taking the time observed to elapse between two successive eclipses,* and multiplying that time by the number of eclipses included in the synodic period of the planet

* At the time of writing his historical statement of the discovery Lardner seems to have been under the impression that Rœmer had computed his table from an observation taken when the earth was at or near to opposition, and that direct observation of the eclipse was then made, throughout the earth's revolution, from each

(Jupiter). (2) That as the earth receded from the planet, the actual commencement of the eclipse was later than the expected time given by the computation, and that this apparent retardation applied to each successive eclipse, so that the interval, by which the commencement of the eclipse was later, continually and regularly increased so long as the earth continued to recede from the planet. (3) That "as the earth again approached opposition, the difference became less and less, until, on arrival at *E.*, the place of opposition, the observed eclipse agreed in time exactly with the computation." †

Referring to the quotation from Herschel's Outlines, which will be found in the Appendix, we have the statement of that astronomer "when the earth comes to *F.*, a point determined by drawing *b. F.* to touch the body of the planet, the emersions will cease to be visible, and will thenceforth, up to the time of the opposition, happen *behind* the disc of the planet. Similarly, from the opposition till the time when the earth arrives at *I.*, a point determined by drawing *a I.* tangent to the eastern limb of Jupiter, the immersions will be concealed from our view." And also, page 14 "It is to be observed that owing to the proximity of the orbits of the first and second satellite to the planet, both the *immersion* and *emersion* of either of them can never be

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successive part of its orbit. But, as shown elsewhere by Lardner himself, such a supposition is inadmissible, because such direct observations throughout a great part of the earth's orbit are not possible. It appears likely that Rœmer obtained his average time, in the first instance, by dividing the synodic period of the planet into the number of the eclipses within that period.

† Lardner's Astronomy.

Plate 6.

Fig. 5.

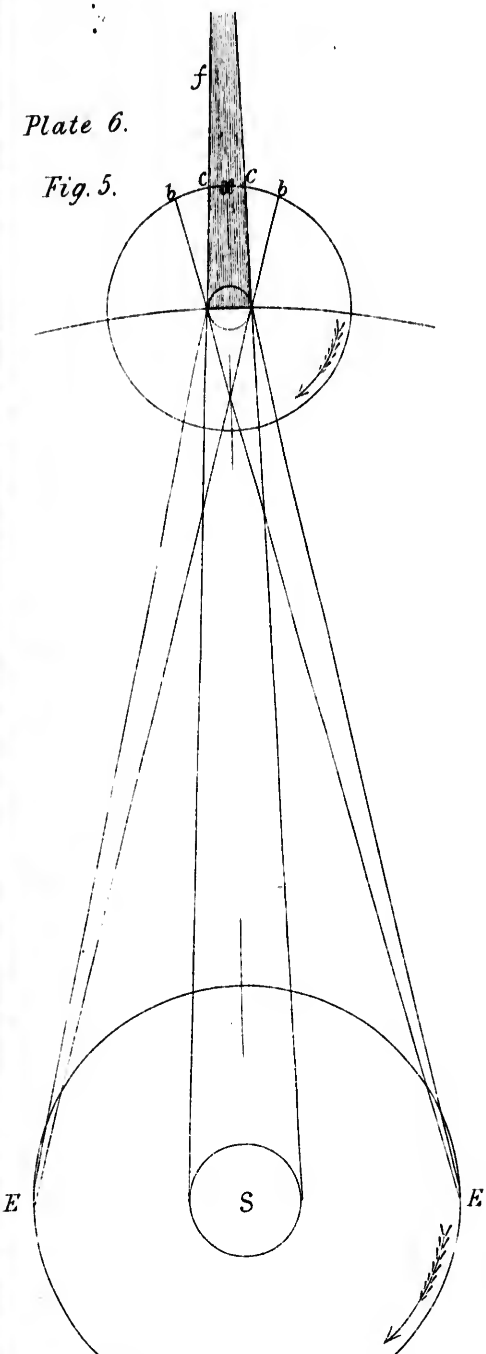
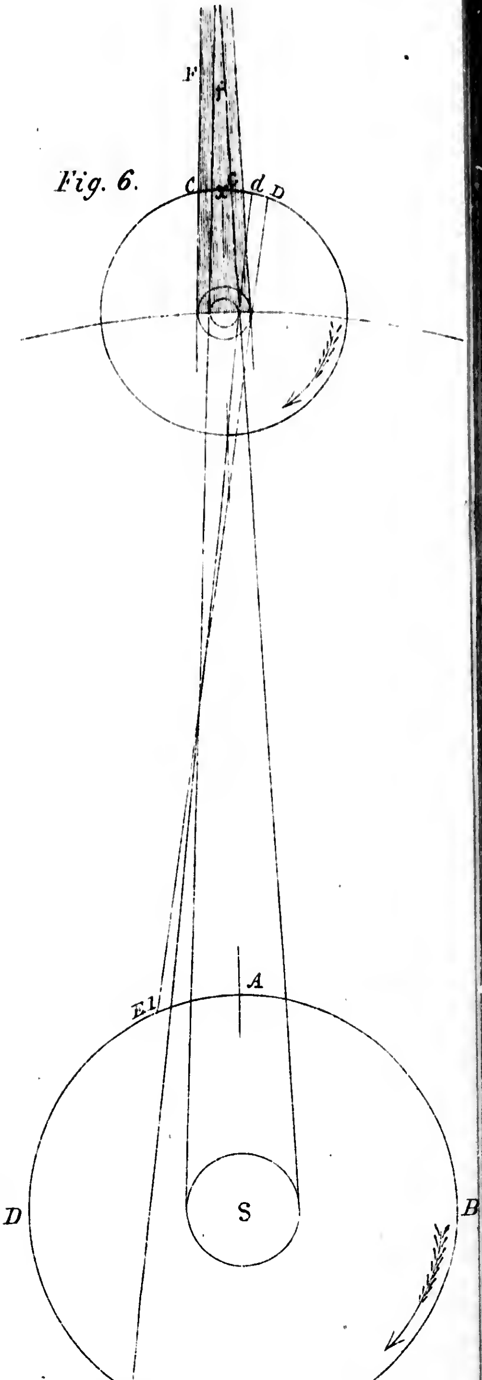


Fig. 6.



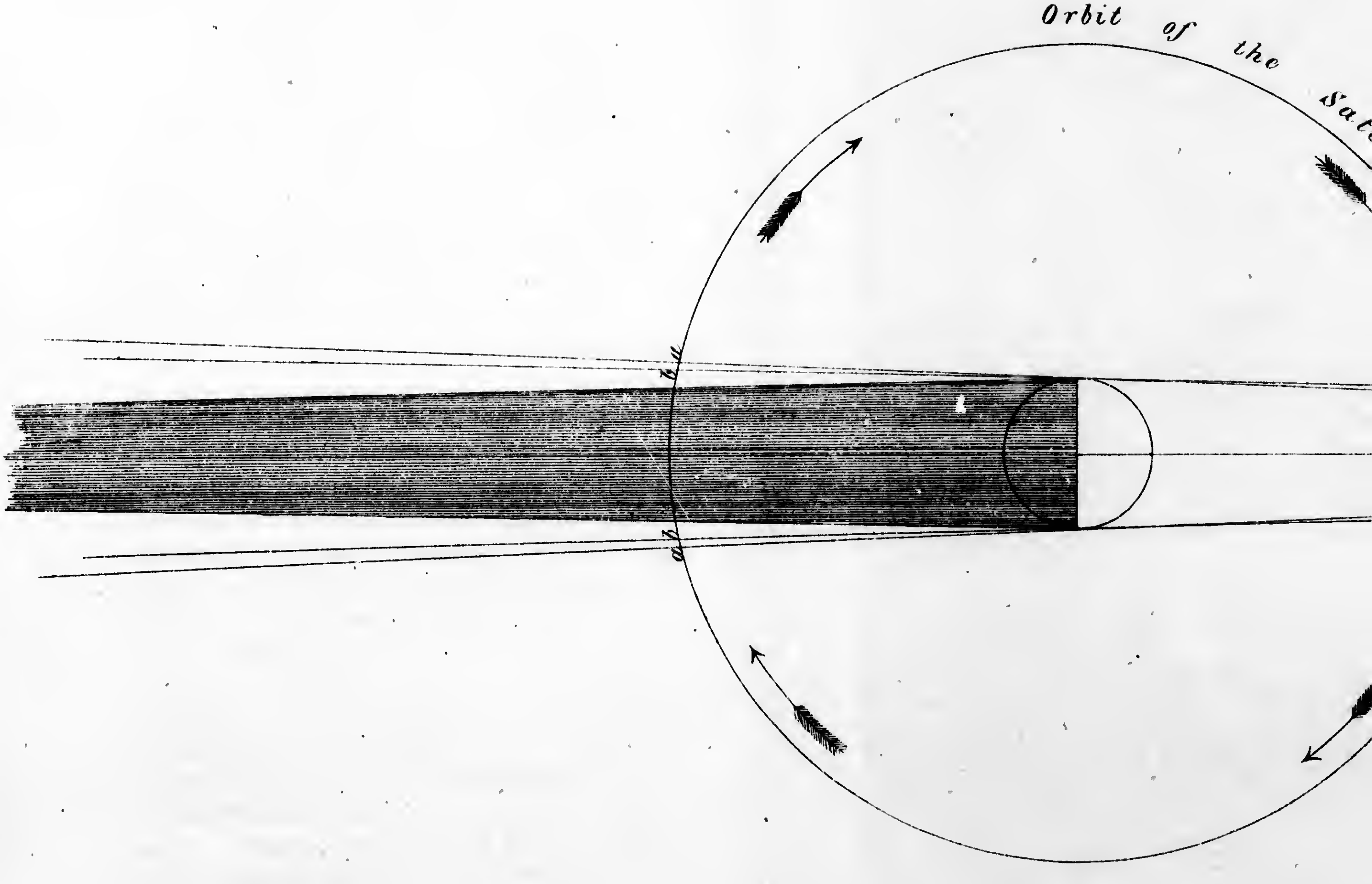
observed in any single eclipse, the immersion being concealed by the body if the planet be past opposition, the emersion if not yet arrived at it, so also of the occultation The commencement of the occultation, or the passage of the sat ellite behind the disc, takes place while obscured by the shadow before opposition and re-emergence after. All these particulars will be easily apparent on mere inspection of the Figure (*See Appendix.*) It is only during the short time that the earth is in the arc *G.H.*, *i.e.*, between the Sun and Jupiter, that the cone of the shadow converging (while that of the visual rays diverges) behind the planet, permits their occultations to be completely observed both at ingress and egress, unobscured, the eclipses being then invisible."

These statements are quite in agreement with those of Lardner himself in his general exposition of the phenomena belonging to Jupiter's shadow and satellites. (See quotation, page 40. "*All these phenomena manifested at quadrature ;* &c., &c.")

It is therefore quite apparent that the circumstances set forth by Lardner, as the result of Roemer's investigation, in regard to the variation in the length of the intervals between the successive eclipses, are not facts of astronomical observation, but are obtained by computation and inference from combined partial observations of the occultations and the eclipses. In the case of the two most distant satellites, when the earth is near quadrature—whether it be receding from or approaching the planet—the commencement and the termination of the eclipses are both visible independently of the occultations, but, with this exception, the times and circumstances of the eclipse are inferred from the commencement of the eclipse and termination of the occultation, or *vice-versâ*. Now in regard to the variation in the apparent breadth of the planet's shadow as the earth approaches towards and recedes from it, it is quite true that no actual alteration takes place. The distance of the planet from the sun remains the same, and the distance of the satellite from the planet the same as before, and if the satellite's immersion and emersion into and out of the shadow could be directly observed, those observations would not be necessarily vitiated or affected by the apparent variation in the size of the planet's shadow: For all the parts and distances of the parts from each other, belonging to the Jovian system, including the planet itself and the planet's shadow, are similarly effected, and, increasing or decreasing in apparent size together, the relative proportions remain the same.

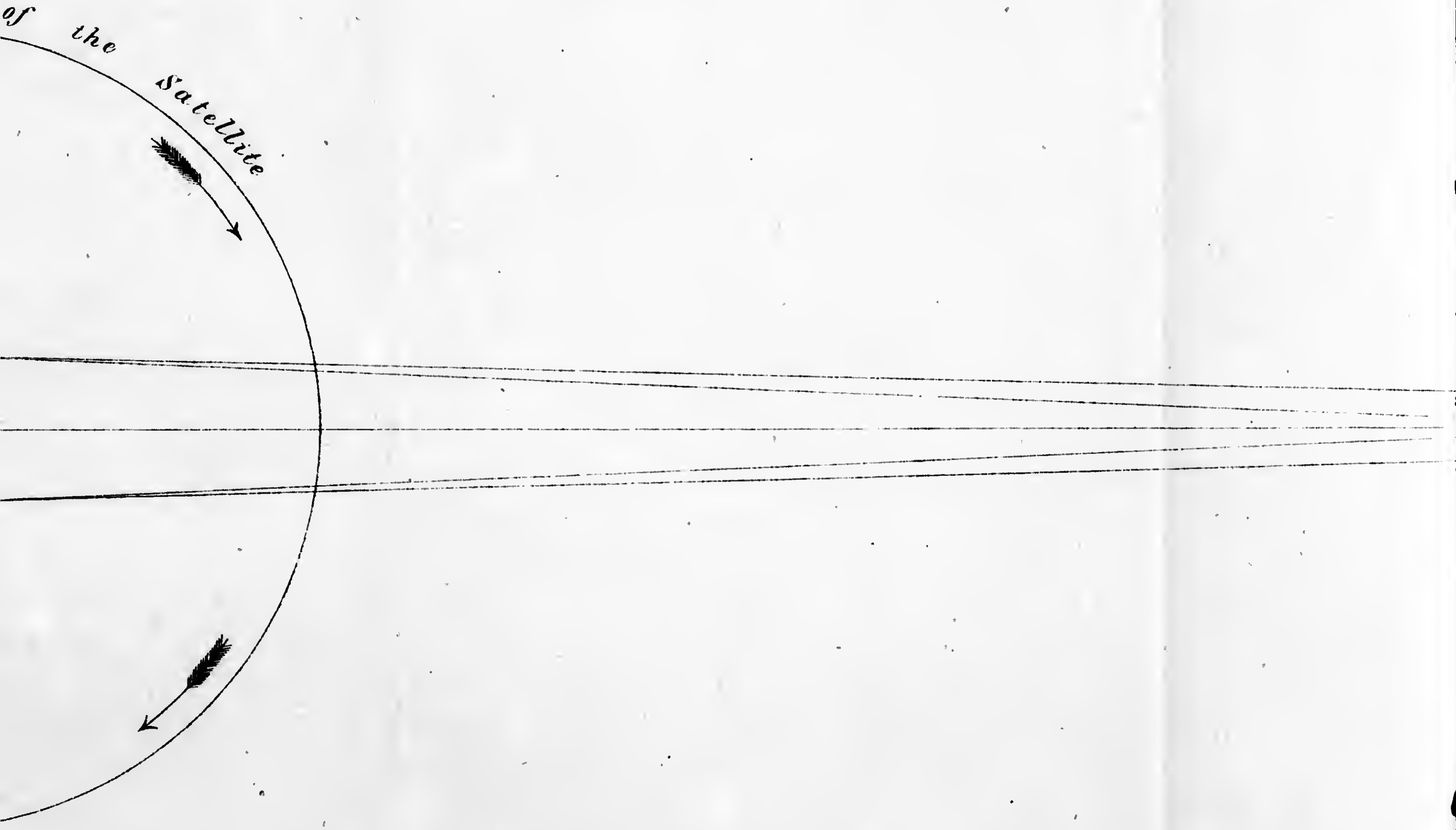
But in regard to the occultation...let us carefully examine whether it may be safely concluded that the approach and recession of the earth towards and from the planet does not cause any variation in the time during which the satellite is hidden from the terrestrial observer; or, to express in other words an equivalent conclusion, whether this approach and recession does not cause any variation in the angular quantity of the satellite's orbital arc cut off by the interposition of the planet: for if there be an arc sometimes of a greater and sometimes of a lesser angular magnitude taken out of the orbital circle, there will evidently be a temporal variation caused in that part of the satellite's revolution which is visible.

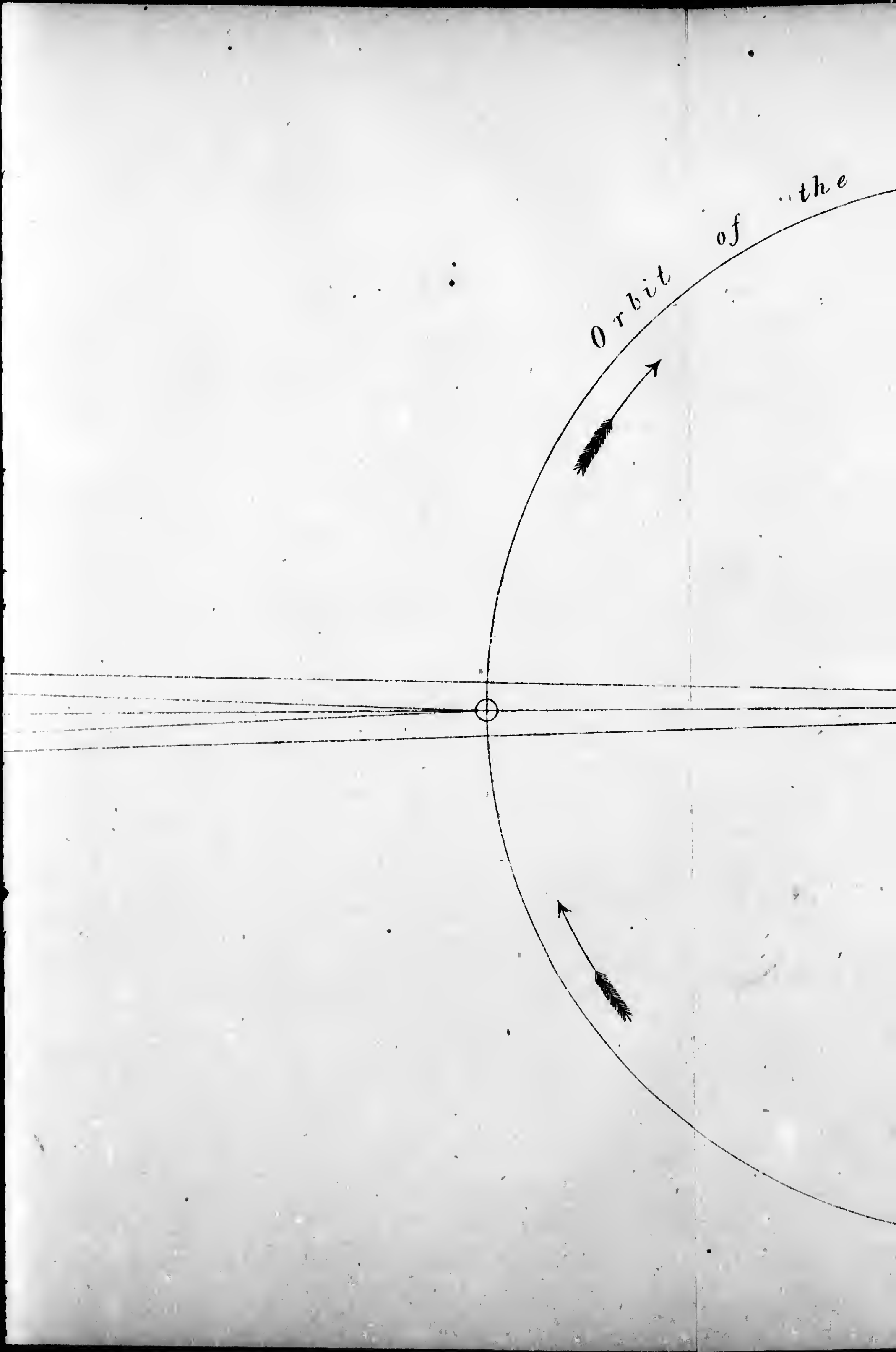
Fig. 10 shows the planet, the orbit of the satellite, the planet's sha low, the sun, and the earth's orbit; the earth of the

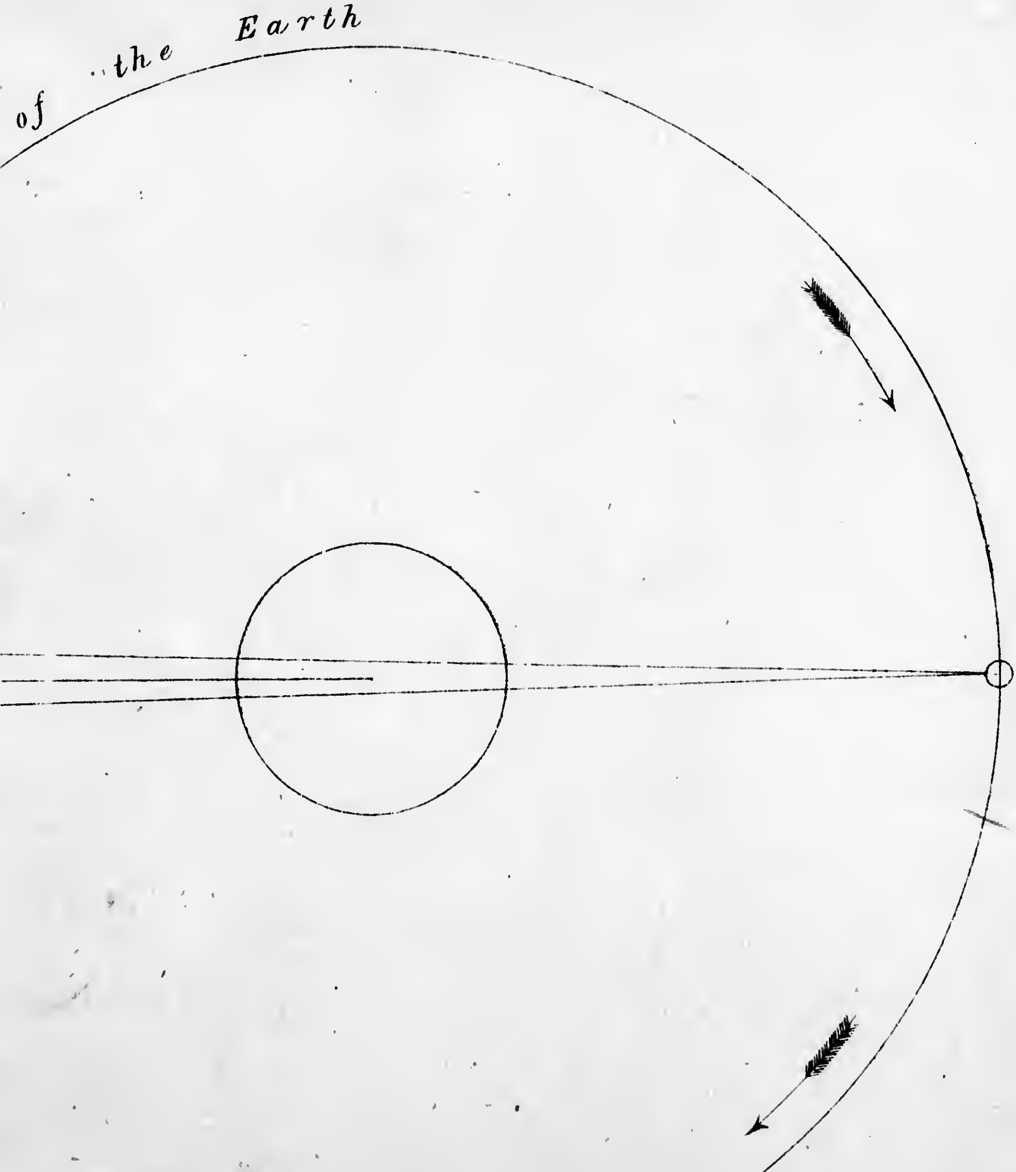

Orbit of the

Occultation of Jupiter's Satellite.

Fig 10.




Orbit of the


of the Earth

is shown at opposition and at conjunction; at those two places, therefore, in the orbit, at which the eclipse of the satellite is entirely hidden from view, and the occultation is completely visible, that is, both the ingress and the egress of the satellite are visible.

Now, by drawing the visual rays from the earth tangent to the disc of the planet..namely, from the earth at opposition and from the earth at conjunction, it becomes at once evident that there is a difference: for the arc *a. a.* of the satellite's orbital circle intercepted by the planet when the earth is least distant, at opposition, has, manifestly, a greater angular magnitude than the arc *b b.* intercepted when the earth is most distant from the planet at conjunction. *Is this difference now recognized by astronomers?* Are those compound observations, which are in part direct in respect to the eclipse, and in part direct in respect to the occultation, rectified relatively to this interfering circumstance? Roemer does not appear to have regarded it; Lardner does not mention it; in Herschel's treatise we do not find any reference to it whatever; nor have we met with any elsewhere; but the difference is a necessary consequence of the varying distance of the earth, and calls for consideration and satisfaction; it is a cause which must have its effect... how is that effect manifested?

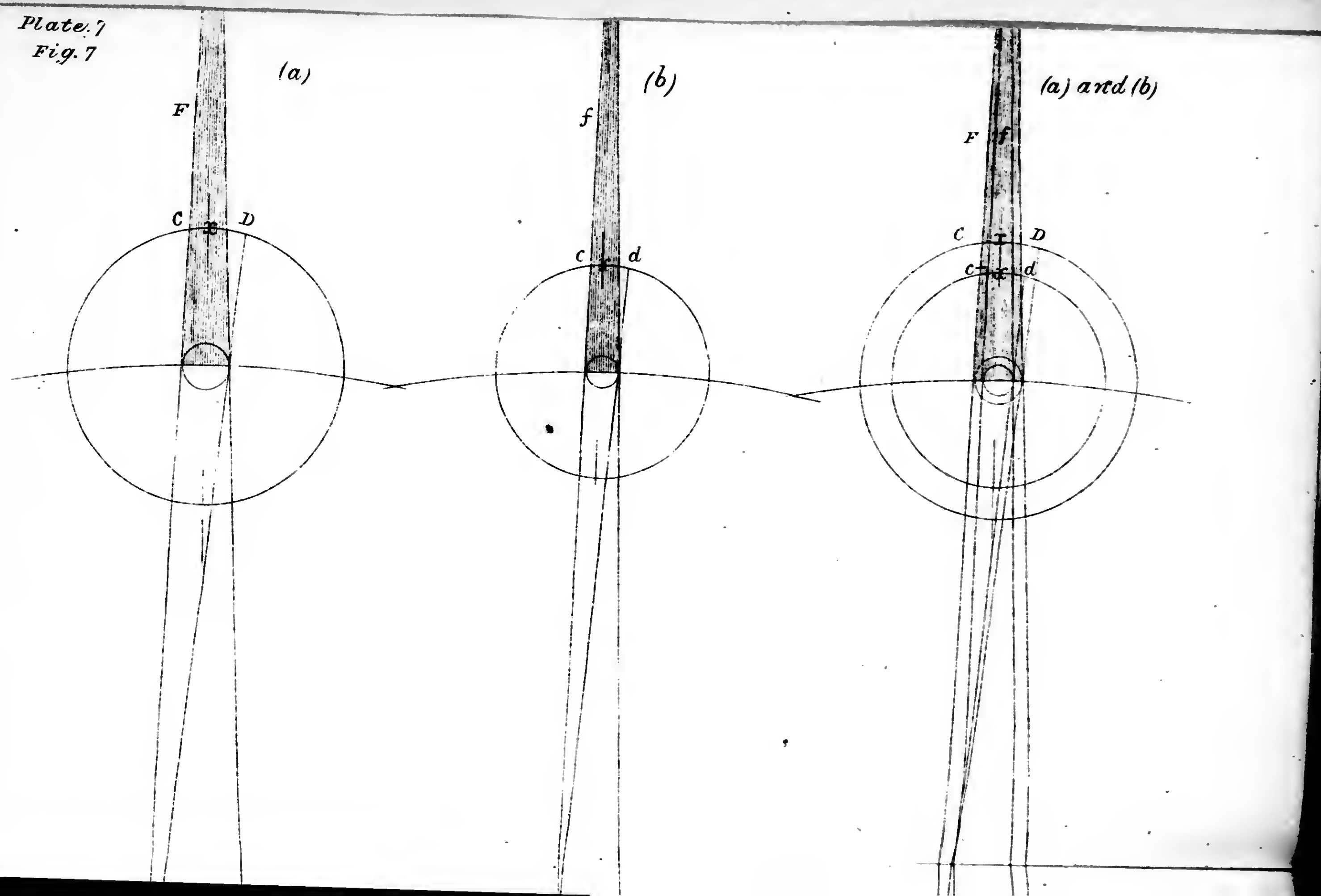
Let us go back to Roemer at the time of his first ascertaining the apparent variation in the interval between the successive eclipses .. to that time when he has just conceived and is about to propose the theory of the velocity of light with the express purpose of accounting for an observed effect to which he can assign no adequate known cause. We now find a cause which must necessarily have its effect, to which no effect appears to have been hitherto assigned, and, moreover, a cause in kind and quantity precisely such as Roemer wanted to enable him to account for his observed effect.

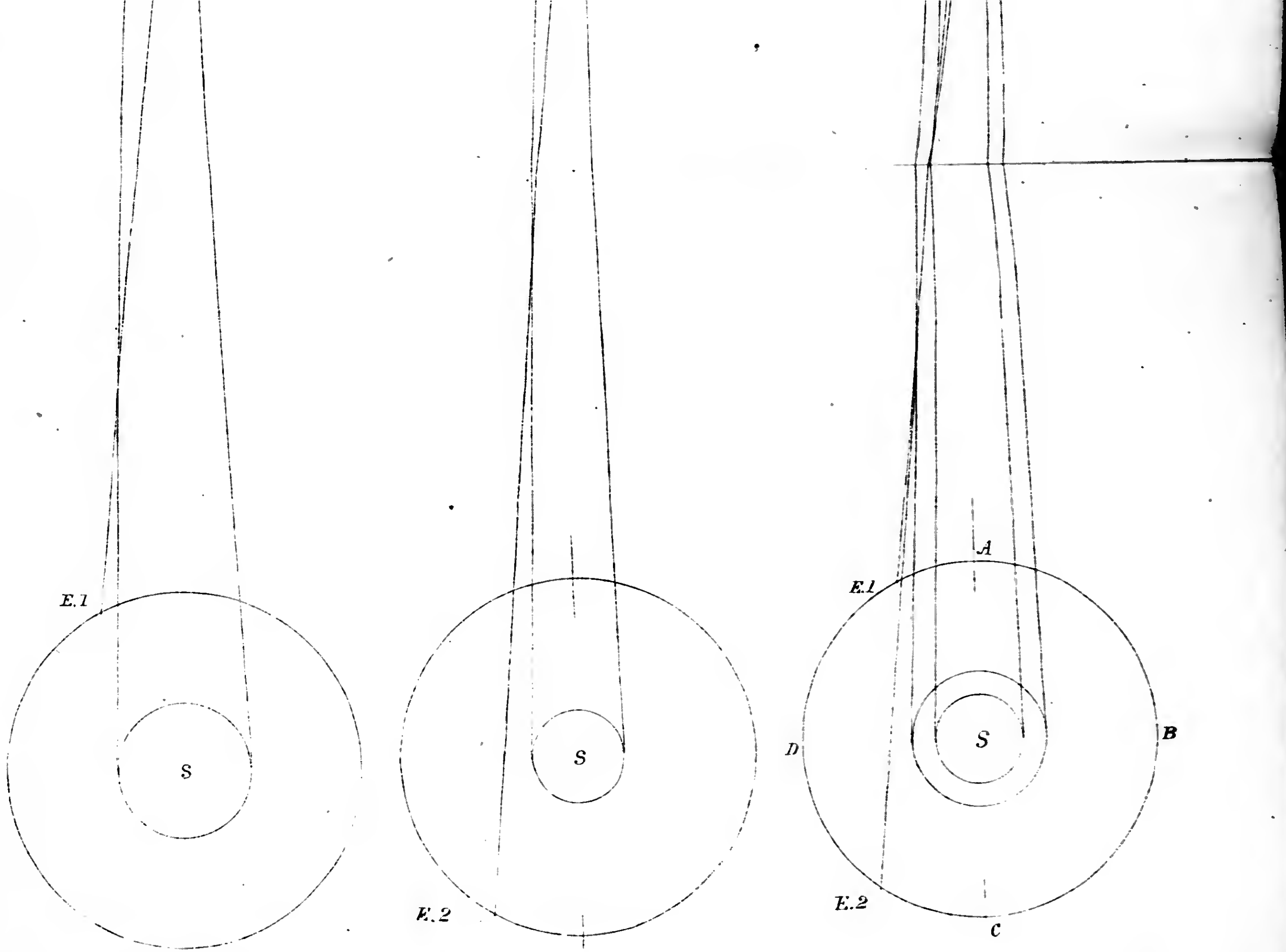
What ground have we for retaining the theory of the velocity of light? It was notoriously suggested at first to supply a cause for a particular effect; and it was based upon that effect....but since it now appears that *that particular effect* is claimed by another cause which has a primary right to it....is there any other basis upon which the theory of the velocity of light may be supported? We opine there is none other, and that the theory must be pronounced untenable, because unsupported by fact.

Note.—It may therefore, be understood that the doctrine we affirm is:—That the actual time of the satellite's revolution is the time established by the direct observations of the eclipse when the earth is near quadrature either east or west; and that the commencement of the eclipse is apparently later when the earth recedes further from the planet, and apparently earlier when the earth approaches nearer to the planet, for the cause stated above and illustrated in the figure, the partial observations of the eclipse being compounded with those of the occultation.

Plate, Fig. 7, may serve as a general representation of the variation in the apparent scale on which the phenomena of the satellite's eclipse and occultation take place, according to whether it is viewed by the terrestrial observer from the earth's most distant or least distant place in its orbit. Fig. 8, which repeats a part of Fig. 7 on a larger scale, illustrates more especially the usual case of the eclipse compounded with the occultation. In

Plate 7
Fig. 7

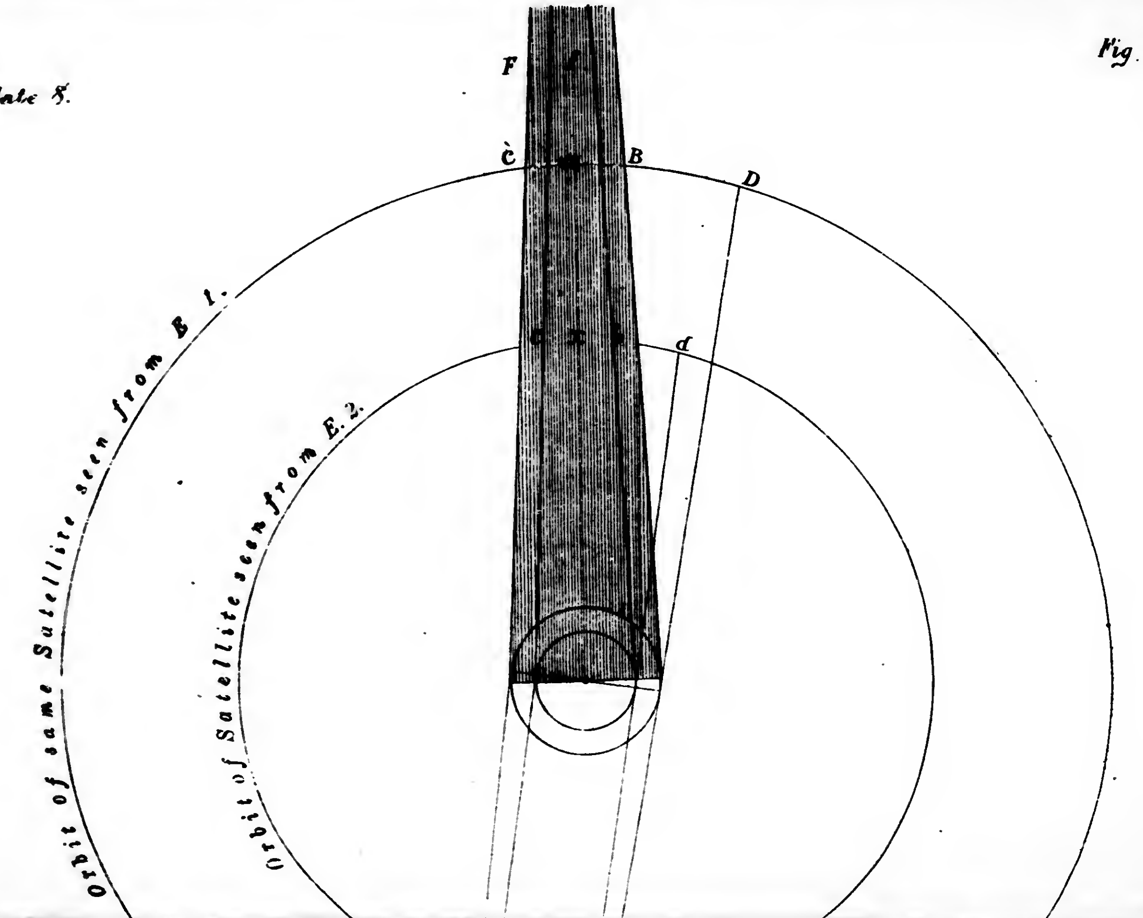




Jupiter's Shadow

Plate 8.

Fig. 8.


Orbit of same Satellite seen from E 1.
Orbit of Satellite seen from E. 2.
F
C
B
D
d

this (Fig. 8.) it is evident that the angle subtended by the arc contained between the outer edge of the shadow on the one side, and the visual ray touching the side of the planet on the other, is greater when the progress of the satellite into the eclipse and out of the occultation, is viewed from the earth at its place of least distance than when viewed from the more distant part of the earth's orbit.

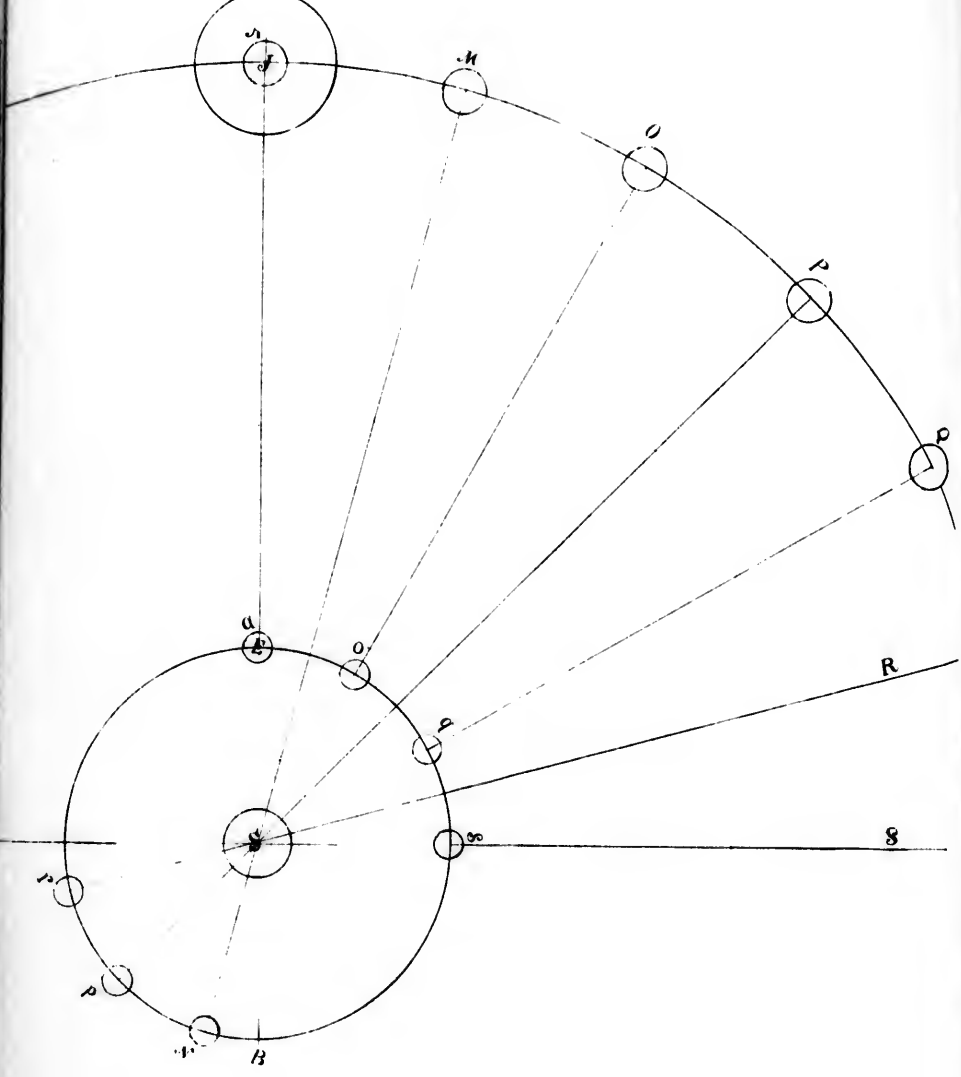
A circumstance worthy of attentive consideration is that, from the statement of the observed facts in regard to the variation in the time of the eclipse as given by Lardner (and which we believe is quite a correct statement of the case as now accepted by astronomers), there does not appear to be any serious difficulty in the way of submitting Roemer's assumption to the direct test of astronomical observation: for, what is contained in that assumption? That each revolution of the satellite when the earth is receding from the planet occupies a longer time than each revolution of the satellite when the earth is approaching the planet; and since the sum of the difference is 16 minutes, it follows that if the number of revolutions made by the satellite in the Synodic period of the planet be *m*., the difference in time of the satellite's revolution will be $32' \div m$, because when viewed from the one side of the orbit as the earth is receding the time of the period is the average period of (the satellite) *increased by* $16' \div m$, and on the other side of the orbit as the earth approaches opposition the time of the period is the average period *less* $16' \div m$; the difference, therefore, is $32' \div m$. But this, again, is the average difference; and evidently at or near the earth's quadrature, when the recession or approach is more rapid, the difference would be greater. If we take the number of revolutions at about 190, the average difference in a single revolution, on the opposite sides of the orbit respectively, would be one-third of a minute, and if at or near quadrature, the difference would, perhaps, exceed half a minute.* Supposing, however, the difference on a single revolution of the satellite to be considerably less than this, it would still be a quantity of time which the practical astronomer can readily verify. This, then, is one of the distinct requisitions of Roemer's assumption which can be directly submitted to the decision of experience.

Let us now consider what effects would be necessarily consequent upon some very small quantity of time being occupied by light, in its communication from the sun to Jupiter, and from Jupiter to the earth. The quantity of *time* attributed by the theory (of the velocity of light) to a certain (definite) quantity of *motion*, seems to us less than reason authorizes the mind to accept as a (reasonable) possibility; or, in other words, the velocity attributed to light, by that theory, seems to us greater than is scientifically conceivable, keeping in mind that, by the theory, this velocity represents the actual progressive motion of a variety or form of matter (*i. e.*, of a material substance). To simplify the consideration of the subject, however, we will assume, for the moment, the possibility of such velocity, and suppose it to be 8 minutes for a distance of 100 million miles. We will take Jupiter's distance roughly

* If the earth receded (and approached) uniformly for equal increments of time, each revolution of the satellite during the recession (or approach), according to the assumption, would lose (or gain) an equal amount of time.

Plate 9.

Fig 9.



at 500 million miles, and thus we obtain at once a more distinct estimate of what the hypothesis involves; for instance, in respect to the entrance of the satellite into the shadow of the planet, as described by Lardner, the assumption of the theory is that the satellite enters the shadow of the planet *in fact* about 40 minutes (on an average) before it appears to us, viewing it from the earth, to do so; and hence, the eclipse must be far advanced before it *appears* to *us* to have commenced.

Let us merely note here that this case is necessarily included in the assumption, and consider other consequents; we will suppose the earth in its orbit, as shewn at *A. a.*, Fig. 9, (Plate 9) with the planet Jupiter in opposition, that is at the orbital place nearest to Jupiter. The earth then travels round to the opposite extremity of the orbit, into conjunction of that planet. If the planet were to remain motionless, this place in the earth's orbit would be *B.* in the Fig.; but, since Jupiter's angular velocity is about one-twelfth that of the earth, the planet will have moved through about 15° to *M.*; and the earth's orbital place of superior conjunction will be *N.* For the earth again to arrive at the place of opposition of the planet, half the earth's solar orbit together with an additional 15° will be the distance required, and *O. o.* will be the place of opposition; *M. O.* being equal to *A. M.*, and *a. o.* equal to twice *B.N.*, and in like manner *P.p.* will be the next place of conjunction, *O. P.* being also equal to *A. M.* So that the distance from opposition to conjunction is in fact equal to the distance from conjunction to opposition; but, on the assumption of the truth of the theory, will this actual equality in the distances also hold good when the motions are observed from the earth? Taking the earth at *a.*, with the planet in opposition, and considering that, as the earth travels in its orbit towards *N.*, the distance of the earth from the planet continually becomes greater and, consequently, an increasing quantity of time is required for the light from the planet to reach the earth, we find that when the earth has arrived at *N.*, this apparent increase in the time actually occupied will, by the theory, amount to 16 minutes. But now as the earth continues its progress, and returns towards opposition, the contrary effect must take place, and the like apparent quantity of time be gained. The result must, therefore, be, if we compare the two halves of the entire synodic revolution of the earth, a difference of 32 minutes. But, moreover, this semi-orbital difference, as measured by time, which belongs to the theory, is not peculiar to the planet Jupiter: it is equally applicable to any other superior planet, because the distance we are here considering is that of the diameter of the earth's orbit. Therefore we have to ask whether there can be a difference in time of about 32 minutes between the two halves of the synodic revolution in the case of each superior planet, which has never yet been observed, or which, in other words, has hitherto escaped the observation of all astronomers?

(*Note.*—It is undesirable in this place to complicate the subject by investigating the additional effect which would arise, under the hypothetical conditions of the case, in consequence of the reversed direction of the earth's orbital motion at opposition and at conjunction respectively. It will be sufficient to observe that, at opposition, light from the planet would, according to the theory, require about 36 minutes to reach the earth which would be then moving from east to west; and at conjunction, about 52 minutes, when the earth would be moving from west to east.)

But let us consider the case of an inferior planet; take, for example, the planet Venus. Now, there is this difference between the case of an inferior and that of a superior planet; that, when the former is in inferior conjunction the solar light passes the planet and comes directly to the earth. When, however, the inferior planet is in superior conjunction, the case is similar to that of the superior planet, and the light of the sun going first to the planet is reflected therefrom to the earth. Herein we observe another favorable opportunity to submit the fundamental assumption of the velocity-of-light theory to the test of fact; for, the transit of Venus furnishes the moment of inferior conjunction almost independently of the velocity hypothesis,* the solar light at that time having a distance of only about 26 million miles to reach the earth, which distance, by the theory, would require a little more than 2 minutes; whereas, at superior conjunction the distance of Venus from the earth is about 165 million miles, requiring by the theory about 14 minutes; a difference in time therefore of about 12 minutes. Let us therefore ask the practical astronomer for a decided answer *on fact* as to whether the planet Venus takes 24 minutes longer to travel from inferior to superior conjunction than it takes

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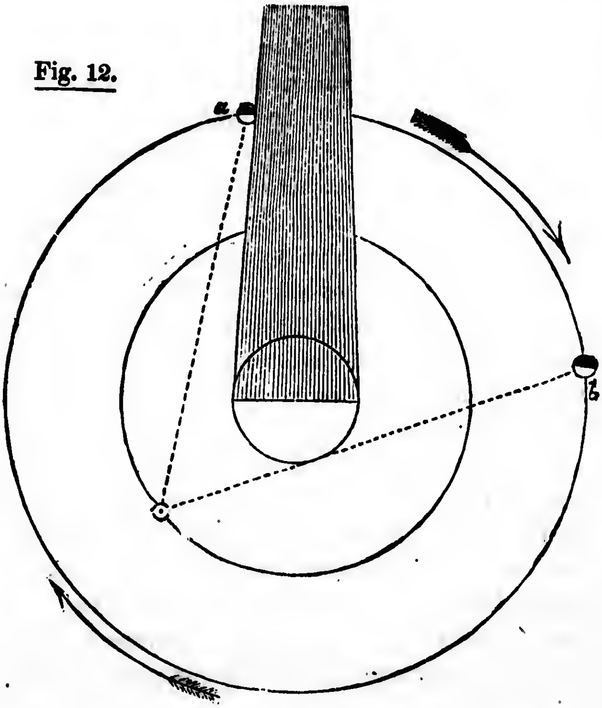
* Because the supporters of the theory expressly reject the testimony of sight as evidencing that what *appears* to take place at a certain time *does actually* take place at the time. We are told. . . No: your sight deceives you; you are reading only the record of the past; what appears to you to be now taking place has *in fact* taken place some time since.

to travel from superior to inferior conjunction .... For it is a requisition of Roemer's assumption that there shall be such difference, and if astronomical observation shows that there is no such difference .. then fact is against the assumption.

Fig. 12.



The combined eclipse and occultation of Jupiter's second satellite viewed from the first satellite; supposing the latter (the first satellite) to remain stationary.

The second satellite is seen entering the western side of the shadow at *a*, and is again seen emerging from behind the eastern limb of the planet at *b*.

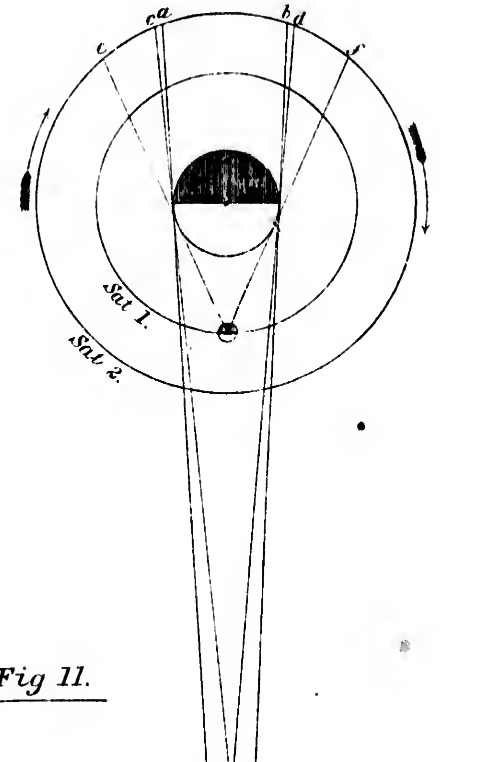


Fig 11.

LIGHT.

We have now examined carefully and attentively those two comprehensive theories of light which have successively received the approval and concurrence of men of science.

Of the two theories *of the nature of light*, Newton's corpuscular or emission theory, which is the oldest and most definite of them, has been given up and discarded in favour of the undulatory theory.

These two theories, although, in many respects, differing widely from each other, are both founded on an assumption that light is in its nature material. . . . that it is either a variety or peculiar description of matter, or else, a dynamical manifestation of matter. By the one theory, a particle of the peculiar matter leaving the luminiferous body by which it is emitted, travels onward in a right line until it comes in contact with the recipient, and the impact of the material particle upon the material body produces the effect termed light. By the other theory a material fluid is supposed, and the effect is conveyed and communicated by means of the material particles of this fluid: a wave, vibration, or impulse, commencing at the luminiferous body, is propagated through and by means of the material particles of the fluid ether, and, again, there is impact, by matter in motion upon the material body of the recipient, occasioning the effect termed light. By either theory, therefore, time is necessarily occupied in the communication of the light from the emittent or luminiferous body to the recipient. .the particles, or the vibrations leave the emittent body, they move through successive spaces, and they arrive at the place of the recipient. Both theories, therefore, belong in common to a primary velocity-of-light hypothesis or theory, and it is as to the reality of the basis upon which this fundamental hypothesis is supposed to rest and upon which the entire superstructure is dependent that the concluding part of our investigation has been directed.

The supposed facts (of observation) upon which the velocity-of-light hypothesis is based, and upon which it is primarily altogether dependent, are three. Of these, the oldest and by far the most important (and which is, indeed, generally looked upon as being alone the fundamental and sure support of the theory), is Roemer's observations of the eclipses of Jupiter's satellites. We have now shown, with respect to those observations, that the velocity-of-light assumption, adopted to explain the variation in the apparent period of the satellites, is a mistake which has arisen in the omission to appreciate the variation in the visual angle occasioned by the increase and decrease of the earth's distance from the planet.

The second of the supposed facts is the so-called *aberration of light*. It has been now shown that the reasoning which attributes certain natural phenomena to such suppositious cause is unsound, and that the aberration theory is merely notional without actual support of fact. It is therefore unreal.

The third supposed fact is the result of certain experiments with Wheatstone's reflecting apparatus. But the result of these experiments as evidence on the primary question, *viz.*, whether light has velocity, was assumed therein; and the actual question which the enquirer proposed thus to submit to experiment, to be answered and determined, was—what is the quantity or amount of the velocity?*

If it be assumed, on the contrary, that light has no velocity, an experiment with an apparatus of this description similarly conducted would, nevertheless, give an apparent velocity as the result, according to the number of reflectors employed; because the light leaves the last reflector subsequently to its leaving the reflector next before it, and, again, it leaves that one subsequently to the one next before that, and so on; and, therefore, in a series of reflectors, a certain time would be occupied in the transmission of the light from one reflector to the next.†

It is true the result of the experiments with this

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* That is to say, time would be occupied in the act of reflection, not in the communication of the light from the surface of the one reflector to the surface of the next.

† In thus stating the question, submitted to experiment, we are according to our view, extending rather than lessening the significance of the question actually submitted. The question submitted was practically..Is that amount of velocity already established exactly correct? The conviction (prejudice) in the minds of those submitting the question being not only that a velocity was established, but that the quantity of velocity had been ascertained either with precision or with a close approximation thereto. In all probability more than a slight discrepancy in the result, from what it was already decided that result must be, would have condemned the apparatus as being in some way unsuitable for the experiment.

apparatus is stated to have been in close agreement with the velocity which had been previously attributed to light; but, when we consider that such an agreement, even if the experiments were conducted with scrupulous precaution and care, might be quite fortuitous, and when we consider, also, that the experiments were undertaken with a foregone conclusion or prejudice of so strong a character that it might be called a conviction, (*i.e.*, an unsound conviction,) not only as to a velocity but also as to the established quantity of that velocity, we cannot allow that these experiments, *viz.*, with Wheatstone's reflecting apparatus, standing alone and unsupported, which they now do, are entitled to be considered as furnishing evidence of value in any degree in regard to the primary question.

Since, therefore, it has been now shown that the several theories, which attribute a material nature to light (meaning thereby the influence which occasions light), are, each of them severally, and all of them collectively, unsound and consequently untenable; and since it has been also shown that the supposed facts of observation, by which the velocity attributed to light was considered to be established, are, in that sense, illusory, and do not, in fact, support such conclusion, we are thrown back upon the primary question. . . . *is light material?* . Now if light be *material* in its nature, it is certain that *time* must be occupied in its transmission; and, inverting the proposition, if no *time* is occupied in its transmission, then it is certain that light is not of a *material* nature. To answer the question in this form we have the positive evidence of Roemer's observations, confirmed by all later observers, of the eclipses of Jupiter's satellites. This is, perhaps, the only positive (direct) evidence* which can, at the present moment be put before the reader as fact demonstrated by direct observation, and as, therefore, indisputable: but it is, we opine, entitled in itself to be considered conclusive; for the distance of the planet Jupiter is so great that, as already stated, any conceivable velocity of a material substance or of an influence transmitted by means of a material fluid (or any description of matter) would necessarily occupy a very appreciable quantity of time in travelling from that planet to the earth: consequently, since it is established by astronomical observation that no appreciable quantity of time is occupied in the transmission from the planet Jupiter, the evidence is positive and decisive that light has no velocity. Wherefore we conclude that the evidence *in fact* is sufficient to answer demonstratively the primary question; and the answer to that question is accordingly —that the nature of light (meaning thereby the influence which occasions light) is spiritual, and not material.

Assuming that the conclusion just stated, in regard to the primary question, is sound; let us now see what secondary conclusions of an important character will follow as corollaries or consequents thereto.

For this purpose it will be convenient to take physical

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* There is much *negative* evidence, some of which we have alluded to, or indicated. Theoretical considerations are, we opine, in the present state of knowledge, if the mind be freed from the prejudice occasioned by the undulatory and other theories, altogether opposed to the idea of light having velocity. If, for example, such a supposition be entertained, it immediately appears to follow that interference and confusion, occasioned by light arriving at the same time from a number of different objects, would necessarily take place.

science, or that division of physical science to which the phenomena of light and sound belong, and to put these conclusions in the form of a brief generalization, making use of certain of the recorded facts, and a part of that common knowledge belonging to the subject, which may be considered certified by science at the present time.

The Physical Forces of Natural Science.

Force is that which causes a change in the condition of matter, overcoming a resistance (antagonism or opposition); which *resistance* is equal in amount to the *quantity* of *force* exerted.

Force is known to us as manifested in several forms or conditions (modes), differing from each other and having its active energy in each condition controlled by definite and distinct laws, which, having been more or less investigated, are now in some measure known.

The several forms or modes of force, now recognized as acting on the material world, and distinguished each from each by the effects on matter of its manifestations, definite and different in the one particular form from those in each of the other forms, are....

	Forms of Force.	*Manifestations of Force on Molecular Matter.*
Force	Electric Force.	Volumetric Electricity. Light.
	Magnetic Force.	Heat. Molecular (Voltaic) Electricity.
	Acoustic Force.	Sound.

		Manifestations of Force on Aggregated Matter.
Force	Dynamic Force.	Motion of Material bodies. Mechanical effect.
	Gravitative Force.	Mechanical effect. Weight or Gravity.

All *change* in the material world is the result of a *manifestation* of *force.* The primary or general law under which all the forms or conditions (modes) of force are manifested and become cognizable by us is that of *succession.*

The *successive manifestations* of *force,* that is, its measurement by the successive effects of its manifestations on matter is known to us as *time.**

Distance is the quantity of separation (*i.e.*, intervening space) between definite localities at which manifestations of force upon matter are cognized.

Force is, therefore, not *material* but *spiritual.* Since the cognition of the material world (*i.e.*, of matter) by the spiritual being, is in ourselves a manifestation or result of *force-energy* acting on *matter,* we cannot divest ourselves of the *idea* of *time* in cognizing matter except in the case of a *simple sensation,* because the successive recognitions of the successive effects is that which we mean by the expression 'idea of time.'

But *matter* itself, in its simple elementary condition, separated from force, is only indirectly known to us. Chemical science teaches us to indirectly recognize the fact that such simple elementary matter is existent †, but it has not been, neither can it be, directly cognized by us apart from its spiritual adjunct *force.*

* This may be familiarly illustrated by reference to the dial-plate of a clock, where the motion of the hour-hand measures the successive vibrations of the pendulum. The measurement may be read off (cognized) in hours, minutes, or seconds, but it is always a measurement from a definite starting point (zero-point), and it expresses the collective cognition of the successive vibrations which have taken place subsequent to that point.

† *But to assume that* chemical evidence, as set forth in the atomic theory, makes us acquainted with simple elementary matter separated from *force* is, perhaps, to assume (*i.e.*, to include the assumption) that matter itself is primarily a materialized (fixed) condition or mode of (gravitative) force.

Therefore all the forms or varieties of compound matter known to us, are compounded of (*the spiritual and the material*) force and matter.

And, also, by an addition to or a deduction from the quantity of *force* contained in a particular form (variety) of matter, the physical condition of that form of (compounded) matter may undergo a change. . although its essential form as distinguished from other forms of (compounded) matter remains unaltered: . . . as, for example water, which by the addition or deduction of that form of force known as *heat*, assumes accordingly the condition of *steam* or of *ice*, in either of which conditions it still remains essentially the same form or variety of (compounded) matter—viz., *water*, as distinguished from all other varieties of matter.

Force in combination with matter may be considered dormant or *latent;* the energy of the force may be said to be employed (in resisting change) in preserving the existence, condition, and form of the compounded matter; it has been (so to speak) *materialized*, and has become (temporarily) a part of the compound matter; but, if the equilibrium of the compounding elements of the body be disturbed by addition or interference of (other) *force*, the condition, or, it may be, the compounded form, of the body must undergo modification or decomposition, and a certain quantity of force, exactly proportional to the quantity of matter acted upon and changed, is set free to manifest its energy as active force, by combining with or disturbing the conditions of, other forms of compounded matter.

Herein we have particular sources of *force* or of manifestations of force-energy within the material world, as known to us. It may be said that the source of all the force-energy usually recognized as belonging to the material world is such a disturbance of existing compounds or combinations, and the consequent setting free of force previously latent or inactive, in the compound. Sidereal (solar) force may be, however, considered as, to some extent, a possible exception* *i.e.*, as, possibly, including an outside source; because, although there is strong probabilility that the active or free force thence derived is the result only of a continuous regulated (material) disturbance of the same character, and that the sun may be correctly understood to act as a reservoir of force, continually collecting and redistributing a regulated supply—nevertheless we cannot be quite sure, in the present state of knowledge, that sidereal (solar) force may not include a more distinct manifestation of outside† spiritual energy, in which case solar force would have have to be looked upon as the primary‡ source of terrestrial force; whereas, otherwise, *i.e.*, assuming the sun to be simply the central recipient and distributor of active force—all terrestrial (or planetary) and solar manifestations of force must be looked upon equally as parts of that collective quantity of force belonging to the solar system.

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* If it be assumed that the aggregate quantity of compound matter in the universe undergoes increase, *i.e.*, that a manifestation of Creative energy is continully or occasionally taking place, a proportionate addition to the collective quantity of force would be, perhaps, necessary, and (it is meant that) the sun, or other central star, may possibly be the medium through which such additional quantity is supplied.

† Meaning thereby . . . a source outside that which is known to us as the material universe.

‡ That is—primary, in a merely terrestrial sense.

Allied Forms of Force

According to the Record of Physical Facts.

A reference to the record of observed facts will show the close relationship of volumetric (frictional) electricity and light.

(*Note.*—It is necessary to remark that certain undemonstrated theories or mere assumptions have been allowed in some cases to mingle with the recorded facts in such wise as to necessitate considerable caution; for example, the theory or assumption of two electricities, or two kinds (varieties) of electricity, having characteristic properties, in some respects directly opposite in the one kind from the corresponding characteristic properties in the other. It was early objected to such assumption that it was superfluous and undemonstrated (unsupported), and a sort of compromise was effected in regard to the nomenclature, by calling the (supposed) one kind *positive*, and the other *negative* electricity. Since that time, however, the illegitimate influence of theory has been still further allowed to usurp the legitimate authority of science, and it seems to be now almost forgotten that the two electricities, or two kinds of electricity, is a mere hypothesis unsupported excepting by a certain superficial appearance of probability which would equally apply to a supposition of 'coldness' being a variety of form of 'heat'; that is to say, to an assumption of two 'heats' or two kinds (varieties of heat), in which certain of the characteristic properties of the one would be the opposite to the corresponding characteristics of the other.)

Volumetric Electricity and Light.

Encyclopedia Britannica.

Art. *Electricity. Part* 1. Sect. V.—*On the Electric Spark.*

"Since the discovery of electric light by Otto Guerick and Dr. Wall, the subject has attracted the particular attention of philosophers. In exciting a glass tube, or in working an electrical machine in the dark, sparks and streams of light are distinctly visible; but the phenomenon is best seen when the knuckles or a brass ball is brought near to an electric conductor. A bright light, called the electric spark, passes from the conductor to the knuckle or ball, and exhibits a great variety of phenomena, varying with the nature and intensity of the electricity, and with the form, magnitude, distance and nature of the bodies between which it passes.

Exp. 1.—Having screwed into a prime conductor a brass ball about two inches in diameter, and projecting about three inches, electrify the conductor positively, and hold another ball near the first. Long ramified zig-zag sparks will pass between the two balls, as shown in Fig. 6, (Pl. 10,) where *pos.* is the positively electrified ball, and *nat*, the one held in the hand in a natural state of electricity. If the ball on the conductor is very small, the spark will become a faint divided brush of light. If the ball on the conductor is electrified negatively, the spark will be as shown in Fig. 7, (Pl. 10.) clear, straight, and more luminous. If one of the balls is positively, and the other negatively electrified, the forms shown in. Fig. 6 and 7, will be combined as in Fig. 8. When, in this last experiment, the distance of the balls is not too great, the positive zig-zag spark will strike the negative straight spark about one-third of the length of the latter from its point, the other two-thirds becoming very luminous. Sometimes the positive spark strikes the negative ball at a distance from the negative spark.

Exp. 4.—Hold an insulated sheet of paper at a small dis-

"tance from a positively electrified conductor, and a beautiful star with distinct radiations will be thrown upon the paper. If the conductor is negatively electrical, a cone of rays, with its base on the paper and its apex on the conductor, will replace the star.

Exp. 5.—If the point of a needle is presented to a positively electrified conductor in the dark, the point will be illuminated with a star; but if the conductor is *negative*, the needle will exhibit a pencil or brush of light.*

The following experiment illustrates the effect of distance on the spark.

Exp. 6.—Fix a sharp-pointed wire to the end of the prime conductor, and having electrified it positively, hold an insulated ball of metal very near the metallic point; a succession of small and *brilliantly white* sparks will pass between them. The white colour will tend to red as the distance of the ball and the point is increased, and at a certain distance the sharp explosions will cease, and a feeble violet light will diverge from the extremity of the point, covering with its base the nearest half of the sphere.

The influence of the form of the body upon the spark which it gives is considerable. Professor Hildebrand, of Erlang, found an obtuse cone with an angle of 52° gave a much more luminous spark than one with an angle of 36°, and he found that the parabolic rounding of the summit, or slight inequalities of the surface, are particularly advantageous in the production of a strong light. The influence of points on the spark has been already described. The nature of the body by which the spark is taken exercises also an influence upon its magnitude and its colour. Professor Hildebrand made some interesting experiments on this subject. The pieces of metal had a conical form, and of the same shape and size. When they were fixed in the same

* The results of these two experiments (4 and 5) are opposed to the theory of two distinct kinds of volumetric electricity ?

"manner at the end of an insulated conductor, the sparks which they yielded differed much in extent. The following table exhibits the results of these experiments, the metals at the head giving the greatest sparks:—

Regulus of Antimony,	Sulphuret of Copper,	Lead.
Gold	Tin	Steel.
Silver	Zinc	do., tempered.
Brass	Iron	" "

When the spark is *white* by taking it with a metallic body, it will, under the same circumstances, be *violet* if taken with the finger. If the spark is taken with ice or water, or a green plant, its light will be red; and if it is taken with an imperfect conductor, such as wood, the light will be emitted in faint streams.

The medium through which the spark is transmitted exercises also a remarkable influence on its colour and form. A spark capable of passing through only half an inch in common air, will pervade six inches of the Torricellian vacuum. The apparatus used by Sir H. Davy for examining the influence of a vacuum, &c., is shown in Fig. 13, where *A.B.C.* is a bent glass tube, *A.* the wire for communicating electricity, *D.* the surface of the quick-silver or fused tin for producing a vacuum, *B.* the tube to be exhausted by the stop-cock *C.* after being filled by means of the same stop-cock when necessary with hydrogen, and *E. F.* the moveable tube connected with the air-pump. Sir H. Davy found, that in all cases when the mercurial vacuum was perfect, it was permeable to electricity, and rendered luminous either by the common spark or the charge of a Leyden jar. The intensity of these phenomena varied with the temperature. When the tube *A.B.C.* was very hot, the electric light appeared on the vapour of the mercurial vacuum of a bright green colour, and of great density. As the temperature diminished it lost its vividness. At 20° below zero of Fahrenheit it was perceptible only in con-

Plate 10.

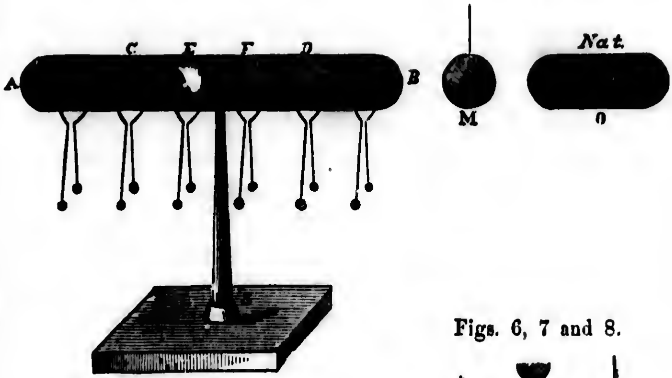
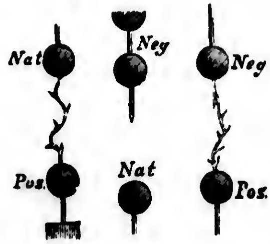


FIG. 1.

Figs. 6, 7 and 8.



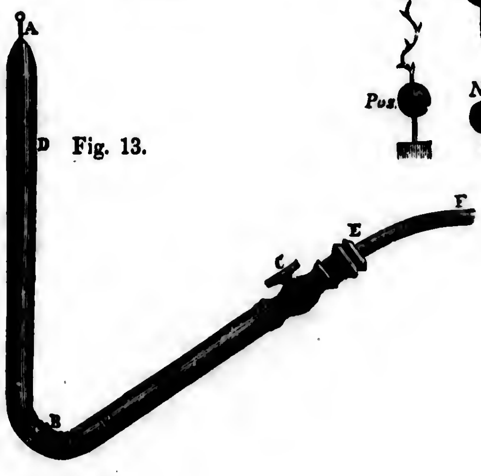


Fig. 13.

"siderable darkness. When the minutest quantity of rare air was introduced into the mercurial vacuum, the colour of the electric light changed from *green* to *sea green*, and by increasing the quantity, to *blue* and *purple*. At a low temperature the vacuum became a much better conductor. A vacuum above fused tin exhibited nearly the same phenomena. At temperatures below zero the light was yellow, and of the palest phosphorescent kind, just visible in great darkness, and not increased by heat. When the vacuum was formed by pure olive oil, and by chloride of antimony, the electric light through the vapour of the chloride was more brilliant than that through the vapour of the oil; and in the last it was more brilliant than in the vapour of mercury at common temperature. The light was of a *pure white* with the chloride, and of a *red* inclining to *purple* in the oil.

Upon rarefying the air five hundred times in a glass vessel a foot long and eight inches in diameter, Mr. Smeaton made the vessel revolve rapidly on a lathe, at the same time exciting it with the palm of his hand. A large quantity of lambent flame appeared under his hand, *variegated with all the colours of the rainbow*. Though the light was steady, every part of it was continually changing colour.

In carbonic acid gas the light of the spark is white and brilliant, and in hydrogen gas it is red and faint. When the sparks are made to pass through balls of wood or ivory they are of a *crimson* colour. They are *yellow* when taken over powdered charcoal, green over the surface of silvered leather, and purple from imperfect conductors.

Exp. 5. The *luminous jar*—shown in Fig. 16—is a still more beautiful experiment. In one which is now before us, fifty-five squares of tin foil an inch square, and each perforated with a hole four-tenths of an inch in diameter, are pasted in five rows on the outside and inside of a glass jar

A.B., Fig. 16, about 5 inches in diameter and 11 inches high.

The diagonals of the square pieces are placed horizontal and vertical, and their points or angles are separated by about one-twelfth of an inch. The rows of the tin-foil squares are similarly placed on the inside of the jar, with this difference only, that their horizontal points nearly touch one another at the centres of the circular holes of the outer squares. The brass ball *A.* communicates with the inside squares by a wire, and when it is charged by the prime conductor, a hundred and ten sparks will be seen at once in a horizontal, and a hundred and ten in a vertical, direction when the jar is discharged.

Exp. 6.—Take a glass cylinder three inches wide and three feet long, so fitted up that a brass plate may be let down from the top of the cylinder, so as to stand at any distance from another brass plate fixed at the bottom of the cylinder. When the cylinder is exhausted of air in the usual manner, and the upper plate communicates with the prime conductor, and the lower one with the ground, a brilliant sheet of light will pass from the upper to the lower plate. If the distance of the plate is ten inches, and if the charge of a Leyden jar is made to pass from the one to the other, a continuous body of the most brilliant fire will pass between them."

Lardner's Natural Philosophy.

Chap.XI.—Luminous Effects of Electricity.

(1810.) "*Electric fluid not luminous.*—The electric fluid is not luminous.* An insulated conductor, or a Leyden jar

* This statement appears to be contradicted instead of supported by what immediately follows.

or battery, however strongly charged, is never luminous so long as the electric equilibrium is maintained and the fluid continues in repose. But if this equilibrium be disturbed, and the fluid move from one conductor to another, such motion is, under certain conditions, attended with luminous phenomena."

(1811.) "*Conditions under which Light is developed by an Electric Current.*—One of the conditions necessary to the development of light by the motion of the electric fluid is, that the electricity should have a certain intensity. If the conductor of an ordinary electric machine while in operation be connected with the ground by a thick metallic wire the current of the fluid which flows through the wire to the ground will not be sensibly luminous; but if the machine be one of great power, such for example as the Taylerian machine of Haarlem, an iron wire 60 or 70 feet long, communicating with the ground and conducting the current will be surrounded by a brilliant light. The intensity of the electricity necessary to produce this effect depends altogether on the properties of the medium in which the fluid moves. Sometimes electricity of feeble intensity produces a strong luminous effect, while in other cases electricity of the greatest intensity developes no sensible degree of light.

"It has been already explained that the electric fluid with which an insulated conductor is charged is retained upon it only by the presence of the surrounding air. According as this pressure is increased or diminished, the force necessary to enable the electricity to escape will be increased or diminished, and in the same proportion.

When a conductor, *B.*, in communication with the ground, approaches an insulated conductor *A.* charged with electricity, the natural electricity of *B.* will be decomposed, the fluid of the same name as that which charges *A.*

"escaping to the earth, and the fluid of the opposite name accumulating on the side of *B.* next to *A.* At the same time, according to what has been explained (1785), the fluid on *A.* accumulates on the side next to *B.* These two *tides* of electricity of opposite kinds exert a reciprocal attraction, and nothing prevents them from rushing together and coalescing, except the pressure of the intervening air. They will coalesce, therefore, as soon as their mutual attraction is so much increased as to exceed the pressure of the air.

This increase of mutual attraction may be produced by several causes. *First*, by increasing the charge of electricity upon the conductor *A.*, for the pressure of the fluid will be proportional to its depth or density.* *Secondly*, by diminishing the distance between *A.* and *B.*, for the attraction increases in the same ratio as the square of that distance is diminished; and, *thirdly*, by increasing

* Herein may be remarked the (perhaps unintentional) expression of a conclusion or prejudice to the effect that the electric influence (force) is a material fluid, and consists of particles which gravitate. If this be not the intended meaning. . . why not have written 'proportional to the quantity?' Some writers on electricity thus use the term 'fluid' (electric fluid) with a sort of protest that they are not to be understood as defining or denoting the character of the influence. They nevertheless use it; and every one is familiarized with the idea of an electric-*fluid* passing or *flowing* in *a current* through a conductor. Thus we have an illustration of some of the consequences of introducing definitions into scientific nomenclature based on vague conjecture. The supposition of the two electricities will not, we opine, be found to be supported by fact; yet it is not, in the existing state of scientific knowledge, unreasonable, and may be considered, for the moment at least, tenable, and therefore a scientific theory. The assumption of that theory is the existence of two electricities—that is, of two positive electricities having certain different and opposite characteristics; and one of these two positive electricities is called negative electricity. The other case (the misuse of the term *fluid*) is, however, much more seriously objectionable; and the supposition therein embodied, if formerly considered to belong to science, has become long since untenable, being contradicted by many of the now well-known facts pertaining to the subject.

F

"the conducting power of either or both of the bodies *A.* and *B.*, for by that means the electric fluids, being more free to move upon them, will accumulate in greater quantity on the sides of *A.* and *B.* which are presented towards each other. *Fourthly*, by the form of the bodies *A.* and *B.*, for according to what has been already explained (1776),* the fluids will accumulate on the sides presented to each other in greater or less quantity, according as the form of those sides approaches to that of an edge, a corner, or a point.

When the force excited by the fluids surpasses the sustaining force of the intervening air, they force their passage through the air, and, rushing towards each other, combine. This movement is attended with light and sound. A light appears to be is produced between the points of the two bodies *A.* and *B.*, which has been called the *electric spark*, and this lumiuous phenomenon is accompanied by a sharp sound like the crack of a whip."

(1812.) "*The Electric Spark.*—The luminous phenomenon called the electric spark does not consist, as the name would

Fig. 11.

imply, of a luminous point which moves from the one body to the other. Strictly speaking, the light manifests no progressive motion. It consists of a *thread of light*, which for an instant seems to connect the two bodies, and in general is not extended between them in one straight unbroken direction, like a thread which might be stretched tight between them, but has a zigzag form resembling more or less the appearance of lightning.

(1813.) "*Electric aigrette.*—If the part of either of the bodies *A.* or *B.* which is presented to the other have the form of a point, the electric fluid will escape, not in the form

* See page 88, *et seq.*

"of a spark, but as an aigrette or brush light, the diverging rays of which sometimes have the length of two or three inches. A very feeble charge is sufficient to cause the escape of the fluid when the body has this form."

(1814.) "*The length of the spark.*—If the knuckle of the finger or a metallic ball at the end of a rod held in the hand be presented to the prime conductor of a machine in operation, a spark will be produced, the length of which will vary with the power of the machine. By the *length of the spark* must be understood the greatest distance at which the spark can be transmitted. A very powerful machine will so charge its prime conductor that sparks may be taken from it at the distance of 30 inches."

(1815.) "*Discontinuous conductors produce luminous effects.*—Since the passage of the electricity produces light wherever the metallic continuity, or, more generally, wherever the continuity of the conducting material is interrupted, these luminous effects may be multiplied by so arranging the conductors that there shall be interruptions of continuity arranged in any regular or desired manner."

(1816.) "*Experimental illustration.*—If a number of metallic beads be strung upon a thread of silk, each bead being separated from the adjacent one by a knot on the silk so as to break the contact, a current of electricity sent through them will produce a series of sparks, a separate spark being produced between every two successive beads. By placing one end of such a string of beads in contact with the conductors of the machine, and the other end in metallic communication with the ground, a chain of sparks can be maintained so long as the machine is worked."

(1817.) "*Effect of rarefied air.*—When the electric fluid passes through air, the brilliancy and colour of the light evolved depends on the density of the air. In rarefied air the light is more diffused and less intense, and acquires "a reddish or violet colour. Its colour, however, is affected, as has been just stated, by the nature of the conductors between which the current flows. When it issues from gold the light is green, from silver red, and from tin or zinc white, from water yellow inclining to orange.


Fig. 12

It is evident that these phenomena supply the means of producing electrical apparatus by which an infinite variety of beautiful and striking luminous effects may be produced. When the electricity escapes from a metallic point in the dark, it forms an aigrette, Fig. 12, which will continue to be visible so long as the machine is worked.

The luminous effect of electricity on rarefied air is exhibited by an apparatus, Fig. 13, consisting of a glass receiver, *b.b.'*, which can be screwed upon the plate of an air-pump and partially exhausted. The electric current passes between two metallic balls attached to rods, which slide in air-tight collars in the cover of the receiver *b.b'*.

Fig. 13.

It is observed that the aigrettes formed by the negative fluid are never as long or as divergent as those formed by the positive fluid, an effect which is worthy of attention as indicating a distinctive character of the two fluids."*

(1828.) "*Experimental imitation of the auroral light*—This phenomenon may be exhibited in a still more remarkable

* Yes; if we suppose two distinct kinds of electricity; but, if there be only one, the explanation may be thus stated:—(1.) The electricity entering at *b.'*, diverges from that ball. (2.) The electricity having been removed from the ball at *b.'*, an equivalent quantity is attracted or gravitates thereto.

"manner by using, instead of the receiver *b.b'.*, a glass tube two or three inches in diameter, and about thirty inches in length. In this case a pointed wire being fixed to the interior of each of the caps, one is screwed upon the plate of the air-pump, while the external knobs of the other is connected by a metallic chain with the primo conductor of the electrical machine. When the machine is worked in the dark, a succession of luminous phenomena will be produced in the tube, which bear so close a resemblance to the aurora borealis as to suggest the most probable origin of that meteor. When the exhaustion of the tube is nearly perfect, the whole length of the tube will exhibit a violet red light. If a small quantity of air be admitted, luminous flashes will be seen to issue from the two points attached to the caps. As more and more air is admitted, the flashes of light, which glide in a serpentine form down the interior of the tube, will become more thin and white, until at last the electricity will cease to be diffused through the column of air, and will appear as a glimmering light at the two points."

(1819.) "*Phosphorescent effect of the spark.*—The electric spark leaves upon certain imperfect conductors a trace which continues to be luminous for several seconds, and sometimes even so long as a minute after the discharge of the spark. The colour of this species of phosphorescence varies with the substances on which it is produced. Thus white chalk produces an orange light. With rock crystal the light first red turns afterwards white. Sulphate of baryta, amber and loaf sugar render the light green, and calcined oyster-shell gives all the prismatic colours."

(1822.) "*Electric light above the barometric column.*—The electric light is developed in every form of elastic fluid and vapour when its density is very inconsiderable. A remarkable example of this is presented in the common barometer. When the mercurial column is agitated so as

" to oscillate in the tube, the space in the tube above the column becomes luminous, and is visibly so in the dark.* This phenomenon is caused by the effect of the electricity developed by the friction of the mercury and the glass upon the atmosphere of mercurial vapour which fills the space above the column in the tube."

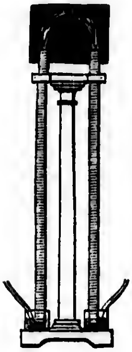


Fig. 14.

(1823.) " *Cavendish's electric barometer*.—The electric barometer of Cavendish, Fig. 14, illustrates this in a striking manner. Two barometers are connected at the top by a curved tube, so that the spaces above the two columns communicate with each other. When the instrument is agitated so as to make the columns oscillate, electric light appears in the curved tube."*

(1824.) " *Luminous effects produced by imperfect conductors.*—The electric spark or charge transmitted by means of the universal discharger and Leyden jar or battery through various imperfect conductors produces luminous effects which are instructive.

Place a small (melon, citron, apple, or any similar fruit on the stand of the discharger; arrange the wires so that their ends are not far asunder, and the moment when the jar is discharged the fruit becomes transparent and luminous. One or more eggs may be treated in the same manner if a small wooden ledge be so contrived that their ends may just touch, and the spark can be sent through them all. Send a charge through a lump of pipe-clay, a stick of brimstone, or a glass of water, or any coloured liquid, and the entire mass of substance will for a short time be rendered luminous. As the phosphorescent appearance induced is by

*We would note this experiment as particularly valuable on the assumption that herein we have the conversion of one form of electric force... namely, motion or mechanical effect, into another form... namely, light.

"no means powerful, it will be necessary that these experiments should be performed in a dark room, and, indeed, the effect of the other luminous electrical phenomena will be heightened by darkening the room.

(1827.) "*Cracking noise attending electric spark.**—The sound produced by the electric discharge is obviously explained by the sudden displacement of the particles of the air, or other medium through which the electric fluid passes."

THE LUMINOUS TRAIN OF THE COMET.

Returning now to the required explanation as to the luminous train of the comet (see conclusion of Part Fourth), let us again state the actual circumstances, such as we found reason in the previous examination of the case to believe them to be . . . namely, circumstances more or less similar in character to those of the primary condition of the earth. (Part Fourth page 12.) "The spherical mass of matter in a liquid (molten or fluid) state, occupying the central part of the body, covered by the solid crust in an intensely heated condition, and surrounded by the vaporous and gaseous envelope, would give the appearance of the 'nucleus' and the 'coma.' Now, if we suppose a quantity of free electricity (*i.e.*, uncombined electric-force in the form of volumetric electricity), belonging to the cometary-mass of matter, to be in a state of disturbance, it is evident from what has been put before the reader that herein

* It will be understood that we do not consider the undulatory theory of sound to be longer tenable. It does not, however, follow, because air is not the cause or origin of sound, that, therefore, air does not conduct sound; on the contrary, the evidence, we opine, is conclusive that air does conduct sound . . . that is to say, conducts that form of *Force* which occasions the effect called sound.—*See Second Division.*

we should have *a cause* of *a* luminous appearance. Are the circumstances, such as we have stated favourable to the supposition? Certainly, they are very favourable; because, since free electricity is readily convertible into that form of electric-force called 'heat,' as, for example, when an imperfect conductor such as a wire is heated and fused by electricity, so is free (active) heat readily convertible into free electricity. It is also apparent that the circumstances known to be favourable to the production of free electricity in the earth's atmosphere...namely, a high temperature of the earth, and a vaporous condition of the air, would be, in the case supposed, far more effective, in consequence of the very high temperature of the solid matter of the comet and the highly vaporous condition of the comet's atmosphere. What would be the probable effect of the sun's influence on a planetary mass (*i.e.*, a comet) in such condition? We shall now show by reference to the observed facts that the probable effect would be to drive the free electricity to that side of the comet opposite to the sun, where it would accumulate, and by which accumulation of electricity, supposing the quantity of it to be very great, the observed appearances of the luminous train would be produced.

For the record of the observed facts we will refer to the same two writers as before.

ELECTRICAL INDUCTION.

*Encyclopedia Britannica,** Chap. 1, Sec. XII.—"*On Electrical Induction, or the decomposition of the combined Electricities by actions at a distance.*—In the preceding sections we have considered the phenomena of electricity as produced by friction, and as communicated or transmitted by conductors to other bodies. But it has been found that electricity may be developed in bodies by the mere influence of

* Sir David Brewster.

"an electrified body placed at a distance, and we shall now proceed to investigate the laws which regulate this interesting class of phenomena.

Let *A*. *B*. Fig. 1 (Pl. 10,) be a cylindrical conductor supported horizontally upon an insulating stand *S*., and having hemispherical ends at *A*, and *B*. Suspend from the points *A*. *B*. *C*. *D*. *E*. *F*. similar pairs of pith balls attached to wires or linen threads, and having insulated it carefully by the stand S. touch it with the finger in order to see that it contains no free electricity. Let an electrified sphere *M*, be now brought near it, so that *A*, *B*, *M*, are in the same straight line, and that no spark can pass from *M*. to *B*. When this has been done, it will be observed that the pith balls diverge as in the figure, the divergency being a maximum at *A*. and *B*. and equal at these points, becoming less at *C*. and *D*. where it is also equal, and still less at *E*. and *F*. where the equality of divergence still exists. Between *E*. and *F*. there will be found some *neutral point* where the pith balls exhibit no divergence, and this point will shift its position according to the distances of the electrified body *M*. If we now suspend an unelectrified pith ball by a silk thread, and bring it near to different parts of the cylindrical conductor, we shall find that it is attracted to it in all places except the *neutral point* between *E*. and *F*.

This *neutral point* is never found in the exact middle of the cylinder between *E*. and *F*. Its position varies with the distance of the body *M*. and with the intensity of its charge. In every case, however, it is nearer to the extremity *B*., next the sphere *M*., than the distant extremity *A*.

From these experiments we are led to the important and curious results, that an *unelectrified body may be electrified by the influence of an electrified body acting upon it at a distance*. The electricity is in this case said to be *induced*, and the phenomenon is called *electrical induction*."

"If we now electrify the pith ball which was suspended by a silken thread, and bring it near to the cylinder *A*. *B*., we shall find that it is *attracted* by one half of the cylinder, from *A*., for example, to the neutral point between *E*. and *F*., and *repelled* by the other half from *B*. to the same neutral point.

From this experiment we infer that *the electricity on one half of the cylinder, from one extremity to the neutral point, is Positive, while the electricity in the other half is Negative*.*

* The inference is, however, based on the hypothesis of the existence of two distinct electricities, or kinds of electricity.

"Bring the electrified pith ball near the electrified body *M.*, and it will be found that, if it was formerly repelled from *A*, it will be attracted by *M.* and *vice versa;* so that we conclude that *the electricity induced upon the half of the cylinders nearest the electrified body is always opposite to that of the electrified body.*

If we now measure the electricity of the body *M.* both before and after the preceding experiments, and make allowance for the dissipation of it through the agency of the adjacent air, we shall find that no part of its electricity has been communicated to the cylinder *A, B.*; and if, while the cylinder *A.B.* is electrified by the inductive influence of *M.*, we either remove *M.* to a distance, or discharge its electricity by touching it with the finger, the electricity of the cylinder *A.B.* will instantly disappear. In like manner, *A.B.* will recover its electrical state the moment that *M.* is brought near it.

Hence it follows that *the positive and negative electricities developed in a conducting body are not communicated to it by that body, but have existed in a state of combination in the substance of the conductor, and have only been separated from their state of combination by the action of the electrified body.*

As the intensity of the positive electricity, as well as its quantity, is the same in one half of the conductor as that of the *negative* electricity is in the other half, and as there is no remaining or free electricity in the cylinder *A.B.* when the body *M.* is withdrawn, it follows that the union or recombination of the two electricities has neutralized or saturated each other. But as the two united electricities have not been destroyed by their union, they exist in a new state which is called the *natural electricity* of bodies. The electricity, therefore, which thus naturally resides in conductors, consists of equal quantities of *positive* and *negative* electricity, which neutralize each other's action, and are consequently incapable of producing any of the phenomena of free electricity, or of a portion of positive or negative electricity existing in a separate state.

With these explanations, we are now able to understand how the cylinder *A.B.* is electrified by the influence of the electrified body *M.* We have clearly proved, by direct experiment, that bodies similarly electrified repel each other; and we have shown in Section X. that this repulsion and attraction does not take place between the material particles of the bodies, but between their electricities, or the electric fluids which they respectively contain. Hence we may enunciate the "law in the following manner:—*Similar electricities repel each other, and dissimilar electricities attract each other.* Now, when the sphere *M*, which we shall suppose to be electrified positively, is brought near the cylinder *A.B.*, in which the electricity exists in its natural or combined state, it will repel all the *positive* electricity, and attract all the *negative* electricity, overcoming the tendency which each has to diffuse itself in virtue of the mutual repulsion of its own particles, and the tendency which the two opposite electricities have to re-combine by their mutual attraction. Hence all the *negative* electricity will be *attracted* to and occupy the half *F.B.* of the cylinder, and all the *positive* electricity will be *repelled,* and occupy the remoter half *E.A.* If *M.* is negatively electrified, the" opposite effects will be produced. Let the body *M.* be now withdrawn, the repulsive and attractive forces which it exercised upon the natural electricity of *A.B.* will cease, and the two electricities, separated by its action, will recombine by their mutual attraction, as well as by the mutual repulsion of the particles of each, and the cylinder *A.B.* will be restored to its natural state of electricity.

The principle of electrical induction which we have now illustrated enables us to give a satisfactory explanation of the phenomena of attraction which have been described in Section II. It was there shown that electrified bodies attracted light and unelectrified bodies that were brought near them; but it will now appear that these apparently unelectrified bodies were first electrified by induction, and, in consequence of the decomposition of their natural electricities, were attracted by the excited body. Thus if *M.* (Fig. 1) is an electrified body placed in a perfect vacuum, and *A.B.* a small light body suspended near *M.*, and capable of moving toward it, then *A. B.* will be so electrified by the influence of *M.* that the electricity of the same name as that of *M.* will be accumulated in the half *F. B.* of the cylinder, and the other electricity in the half *E.A.* But the electricity of *M.* attracts that of *B.F.* more powerfully than it repels that of *E. A.*, and consequently the light body *A. B.* will be attracted to *M.* in consequence of the previous decomposition of its native electricity. If this decomposition cannot be effected by *M.*, or if it takes place with difficulty, the body *A. B.* will not be attracted, or will be attracted less readily."

M. Biot has illustrated this position by the following simple experiment: "Suspend by fine silk threads two small balls of equal "dimensions, one of them being made of pure gum-lac, and the other of gum-lac either gilt on its surface or covered with a thin plate of tin foil. When these two balls are placed beside each other, and at a small distance, bring near them an electrified tube of glass or sealing-wax, and it will be seen that the gilt ball will be more strongly and easily attracted than the other. The uncoated ball of lac will not begin to be attracted till after a certain time, when the decomposition of its natural electricity has been effected; and thus its electrical state will continue after the removal of the electrical body."

In examining the action of *M.* upon *A.B.* (Fig. 1,) we supposed that no change took place in the electrical condition of *M.*; but this is not the case, for the body *A.B.* as soon as its natural electricity has been decomposed, begins to react upon *M.* through the agency of its separated electricities. These separated electricities not only tend by their attractive and repulsive forces to change the distribution of the free electricity which exists in *M.*, but also to decompose its natural electricity, and thus to increase its free electricity by one of the two separated electricities. When this change has been effected upon the electrical state of *M.*, its action upon *A.B.* will also change. It will decompose a new quantity of the natural electricity of *A. B.* and distribute the positive and negative electricities of which it is composed in the halves *A.E.*, *B.F.*; and these new portions will again react upon *M.* till a permanent equilibrium is effected among all the attractive and repulsive forces which are thus brought into play." * * *

"If we connect *A.B.* with the earth, after removing it from the sphere *M.* it will be found charged with an excess of the electricity opposite to that of *M.*

"In all these experiments on induction, the charged sphere *M.* the inducing body, suffers no loss of electricity from having exercised its inductive action."

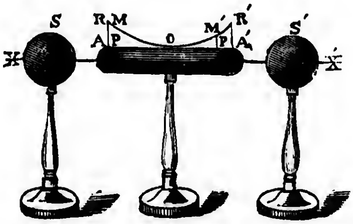
Lardner's Natural Philosophy, Chap. VIII.

(1728.) "INDUCTION—*Action of Electricity at a distance.*—If a body *A.* charged with electricity of either kind be brought into proximity with another body *B.* in its natural state, the fluid with which *A.* is surcharged will act by attraction and repulsion on the two constituents of the natural electricity of *B.* attracting that of the contrary, and repelling that of the same kind. This effect is precisely similar to that produced on the natural magnetic fluid in a piece of iron when the pole of a magnet is presented to it.

"If the body *B.* in this case be a non-conductor, the electric fluid having no free mobility on its surface, its decomposition will be resisted, and the body *B.* will continue in its natural state, notwithstanding the attraction and repulsion exercised by *A.* on the constituents of its natural electricity. But if *B.*, be a conductor, the fluids having freedom of motion on its surface, the fluid similar to that with which *B.* is charged will be repelled to the side most distant from *B.* and the contrary fluid will be attracted to the side next to *B.* Between these regions a neutral line will separate those parts of the body B. over which the two opposite fluids are respectively diffused."

(1729.) "*Induction Defined.*—This action of an electrified body exerted at a distance upon the electricity of another body is called *Induction,* and is evidently analogous to that which produces similar phenomena in the magnetic bodies (1630.)"

(1730.) "*Experimental Exhibition of its Effects.*—To render it experimentally manifest, let *S.* and *S'.*, Fig. 476, be two metallic balls, supported on glass pillars: and let *A. A'.* be a metallic cylinder



similarly mounted, whose length is ten or twelve times its diameter, and whose ends are rounded into hemispheres. Let *S.* be strongly charged with positive, and *S'.* with negative electricity, the cylinder *A. A'.* being in its natural state. Let the balls *S.* and *S'.* be placed near the ends of the cylinder *A. A'.* their centres being in a line with its axis, as represented in the figure.

The positive electricity of *S.* will now attract the negative, and repel the positive constituent of the natural electricity of *A. A'.*, so as to separate them, drawing the negative fluid towards the end *A.* and repelling the positive fluid towards the end *A'.*

Since the cylinder *A. A'.* is a conductor, and therefore the fluids have freedom of motion on its surface, this decomposition will take effect, and the half *O. A.* of the cylinder next to *S.* will be charged "with negative, and the half *O. A'.* next to *S'.* with positive electricity.

That such is in fact the condition of *A. A'.* may be proved by presenting a pith ball pendulum charged with positive electricity to either half of the cylinder. When presented to *O. A'.* it will be repelled, and when presented to *O. A.* it will be attracted.

If the two balls *S. S.'* be gradually removed to increased but equal distances from the ends *A.* and *A'.*, the composition of the fluids will gradually take place; and when the balls are altogether removed the cylinder *A. A'.* will recover its natural state, the fluids which had been separated by the action of the balls being completely recombined by their mutual attraction.

Let a metallic ring *n'.* be supported on a rod or hook of glass *n.*, and let two pith balls *b. b'.* be suspended from it by fine wires, so that when hanging vertically they shall be in contact. Let a ball of metal *r.*, strongly charged with positive electricity, be placed over the ring *n'.* at a distance of eight or ten inches above it. The presence of this ball will immediately cause the pith balls to repel each other, and they will diverge to increased distances the nearer the ball *r.*, is brought to the ring *n'.*

Fig. 477.

If the ball *r.* be gradually raised to greater distances from the ring, the balls *b. b'*, will gradually approach each other, and will fall to their position of rest vertically under the ring when the ball *r.* is altogether removed. If the charge of electricity of the balls *S.* and *S'*. Fig. 476, or of the ball *r.*, Fig. 477, be gradually diminished, the same effect will be produced as when the distance is gradually increased; and, in like manner, the gradual increase of the charge of electricity will have the same effect as the gradual diminution of the distance from the conductor on which the action takes place.

If the ring *n'.*, the balls *b. b'.*, and the connecting wire be first feebly charged with negative electricity, and then submitted to the inductive action of the ball *r.* charged with positive electricity, placed as before above the ring, the following effects will ensue. When the ball *r*, approaches the ring, the balls *b. b'.* which previously diverged, will gradually collapse until they come into contact, As the ball *r.* is brought still nearer to *n'.* they will again diverge, and "will diverge more and more, the nearer the ball *r.* is brought to the ring.

These various effects are easily and simply explicable by the action of the electricity of the ball *r.* on that of the ring. When it approaches the ring, the positive electricity with which it is charged decomposes the natural electricities of the ring, repelling the positive fluid towards the balls. This fluid combining with the negative fluid * with which the balls are charged, neutralizes it, and reduces them to their natural state: while this effect is gradually produced, the balls *b. b'.* lose their divergence and collapse. But when the ball *r.* is brought still nearer to the ring, as more abundant decomposition of the natural fluid is produced, and the positive fluid repelled towards the balls is more than enough to neutralize the negative fluid with which they are charged; and the positive fluid prevailing, the balls again diverge with positive electricity.

These effects are aided by the attraction exerted by the positive electricity of the ball *r.* on the negative fluid with which the balls *b. b'*, are previously charged.

If the electrified ball, instead of being placed above the ring, be placed at an equal distance below the balls *b. b'.*, a series of effects will be produced in the contrary order, which the student will find no difficulty in analysing and explaining. If the ball *r.* be charged with negative, it will produce the same effects when presented above the ring, as when, being charged with positive electricity, it is presented below it.

In all cases whatever, the conductor whose electrical state has been changed by the proximity of an electrified body returns to its primitive electrical condition when the disturbing action of such body is removed *; and this return is either instantaneous or gradual."

(1776.) "*Effects of edges and points.*—If the conductor be a flat disc, the depth of the fluid will increase from its centre towards its edges. The depth will, however, not vary sensibly near the centre

* If we reject the dual-fluid hypothesis, the explanation will differ from the above, inasmuch as there will then be no negative fluid to neutralize. The balls have been, in the first place, deprived of their electricity; but the approach of the ball *r.* charged with positive electricity, repels the electricity from the ring to the balls which thus acquiring their natural (normal) amount of electricity no longer repel each other and fall together.

" but will augment rapidly in approaching the edge, as represented in Fig. 508, where *A.* and *B.* are the edges and *C.* the centre of the disc, the depth of the fluid being indicated by the dotted line.

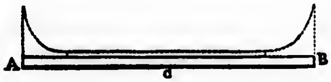


Fig. 508.

It is found in general that the depth of the fluid increases in a rapid proportion in approaching the edges, corners, and extremities, whatever be the shape of the conductor. Thus, when a circular disc or rectangular plate has any considerable magnitude, the depth of the electricity is sensibly uniform at all parts not contiguous to the borders; and whatever be the form, whether round or square, if only it be terminated by sharp, angular edges, the depth will increase rapidly in approaching them.

If a conductor be terminated, not by sharp, angular edges, but by rounded sides or ends, then the distribution will become more uniform. Thus, if a cylindrical conductor of considerable diameter have hemispherical ends, the distribution of the electricity upon it will be nearly uniform; but if its ends be flat, with sharp, angular edges, then an accumulation of the fluid will be produced contiguous to them. If the sides of a flat plate of sufficient thickness be rounded, the accumulation of fluid at the edges will be diminished.

The depth of the fluid is still more augmented at corners where the increase of depth due to two or more edges meet and are combined; and this effect is pushed to its extreme limit if any part of a conductor have the form of a *point*.

The pressure of the surrounding air being the chief, if not the only force, which retains the electric fluid on a conductor, it is evident that if at the edges, corners, or angular points, the depth be so much increased that the elasticity of the fluid exceeds the restraining pressure of the atmosphere, the electricity must escape, and in that case will issue from the edge, corner, or point exactly as a liquid under strong pressure would issue from a *jet d'eau.*"

(1777.) " *Experimental illustration of the effect of a point.*—Let *P.* (Fig. 509) be a metallic point attached to conductor *C.*, and let the perpendicular *n.* express the thickness or density of the electric fluid

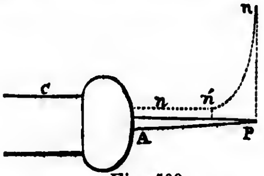


Fig. 509.

at that place; this thickness will increase in approaching the point *P.* so as to be represented by perpendiculars drawn from the respective points of the course *n.n.'n.''* to *A. P,* so that its density at *P.* will be expressed at the perpendicular *n''. P.* Experience shows that in ordinary states of the atmosphere a very moderate charge of electricity given to the conductor *C.* will produce such a density of the electric fluid at the point *P.* as to overcome the pressure of the atmosphere, and to cause the spontaneous discharge of the electricity.

The following experiments will serve to illustrate the escape of electricity from points:

Let a metallic point, such as *A. P.*, (Fig. 509,) be attached to a conductor, and let a metallic ball of two or three inches in diameter, having a hole in it corresponding to the point *P.*, be stuck upon the point. If the conductor be now electrified, the electricity will be diffused over it, and over the ball which has been stuck upon the point *P.* The electric state of the conductor may be shown by a quadrant electrometer being attached to it. Let the ball now be drawn off the point *P.* by a silk thread attached to it for the purpose, and let it be held suspended by that thread. The electricity of the conductor *C.* will now escape by the point *P.*, as will be indicated by the electrometer, but the ball suspended by the silk thread will be electrified as before."

(1778.) *Rotation produced by the reaction of points.*—Let two wires *A. B.* and *C.D.*, (Fig. 510) placed at right angles, be supported by a

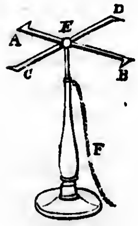


Fig. 510.

cap *E.* upon a fine point at the top of an insulating stand, and let them communicate by a chain *F.* with a conductor kept constantly electrified by a machine. Let each of the four arms of the wires be terminated by a point in a horizontal direction at right angles to the wire, each point being turned in the same direction, as represented in the figure. When the electricity comes from the conductor to the wires it will escape from the wires at these four points respectively; and the force with which it leaves them will be attended with a proportionate recoil,* which will cause the wire to spin rapidly on the centre *E.*

(1779.) "*Another experimental illustration* of this principle.—An apparatus supplying another illustration of this principle is represented in Fig. 511; a square wooden stand *T.* has four rods of glass inserted in its corners, the rods at one end being less in height than those at the other. The tops of these rods having metal wires *A. B.* and *C. D.* stretched between them, across these wires another wire *E. F.* is placed, having attached to it at right angles another *G.H.* having two points turned in opposite direction at its extremities, so that when *G. H.* is horizontal these two points shall be vertical, one being presented upwards and the other downwards. A chain from *B.* communicates with a conductor kept constantly electrified by a machine. The electricity coming from the conductor by the chain, passes along the system of wires and escapes at the points *G.* and *H.* The consequent recoil causes the wire *G. H.* to revolve round *E. F.* as an axis, and thereby causes *E. F.* to roll up the inclined plane."

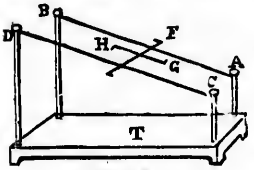


Fig. 511.

(1794.) "*Curious effect of repulsion of pith ball.*—Let a metallic point be inserted into one of the holes of the prime conductor, so that, in accordance with what has been explained, a jet of electricity may escape from it when the conductor is electrified. Let this jet, while

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*It may be well again to remind the reader of the hypothesis of an imponderable but material fluid . . . a hypothesis scientifically inadmissible, but which Dr. Lardner appears to have practically accepted. Disallowing that hypothesis, it does not quite follow that the electric force, being spiritual, may not or might not have an action on the particles of air such as seems to be here indirectly attributed to it; we opine, however, that the evidence is quite insufficient to substantiate such conclusion. If the effect is *recoil* in the material and usual sense, the case is one of action and reaction. Evidently the air should have motion imparted to it. Is there any evidence of such effect? Let the apparatus with its four arms (Fig. 510.) be prevented from rotating, and let it be shown that the escape or discharge of electricity causes motion in the air in the opposite direction, *i.e.* moves away the air from each of the points, tangentially to the circle.

the machine is worked, be received on the interior of a glass tumbler, by which the surface of the glass will become charged with electricity.

If a number of pith balls be laid upon a metallic plate communicating with the ground, and the tumbler be placed with its mouth upon the plate, including the balls within it, the balls will begin immediately leaping violently from the metal and striking the glass, and this action will continue till all the electricity with which the glass was charged has been carried away.

This is explained on the same principle as the former experiments. The balls are attracted by the electricity of the glass, and when electrified by contact, are repelled. They give up their electricity to the metallic plate, from which it passes to the ground; and this process continues until no electricity remains on the glass of sufficient strength to attract the balls."

Lardner's Natural Philosophy. (1796.) *Curious experiments on electrified water.*—"Let a small metallic bucket *B.*, Fig. 519, be suspended from the prime conductor of a machine, and let it have a capillary tube *C. D.*, of the siphon form, immersed in it; or let it have a capillary tube inserted in the bottom; the bore of the tube being so small that water cannot escape from it by its own pressure. When the machine is put in operation, the particles of water, becoming electrified, will repel each other, and immediately an abundant stream will issue from the tube; and as the particles of water after leaving the tube still exercise a reciprocal repulsion, the stream will diverge in the form of a brush.

If a sponge, saturated with water, be suspended from the prime conductor of the machine, the water, when the machine is first worked, will drop slowly from it; but when the conductor becomes strongly electrified, it will descend abundantly, and in the dark will exhibit the appearance of a shower of luminous rain."

(Note.) In connection with this the reader may be reminded of the occasionally luminous appearance of (seawater) the surface of the ocean in the very beautiful phenomenon known as the phosphorescence of the sea.*

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* This "phenomenon is usually attributed, incorrectly we opine, to the presence of some form of animal or vegetable life, which is supposed to be distributed on the surface in vast numbers of minute individuals.

To apply these examples to the case of the comet. If we consider the sun as the body charged with electricity, and the comet as the insulated conductor, it becomes readily understood that the inductive power of the sun will cause the electricity of the comet to accumulate on the side opposite to itself. We have already called attention to the fact that the physical condition of the matter at the comet's surface must be highly favourable to the development of free electricity or, to speak more strictly, to the elimination of force in the form of free volumetric electricity. The sun's action on the comet, will consequently result in an accumulation of electricity at the side of the comet most remote from the sun, and which, being luminous, will account for the observed phenomenon known as the luminous train.*

* It may be supposed that when the distance from the sun again becomes greater, a part of the free electricity may be reconverted into caloric force, and the quantity undergo diminution by its communication as radiant heat to other aggregated masses of matter. A supposition, however, subject to an approach and recession of the comet in respect to the sun being established in fact. Unless under very exceptional circumstances, we opine, as already stated and argued, that the comet's distance from the sun (or other centre of gravitation) does not greatly vary.

SECOND DIVISION.

(1.) THE UNDULATORY OR WAVE-THEORY OF SOUND.

In commencing a brief examination of this theory of sound, it is in the first place to be remarked, that the term wave-theory more properly belongs to the original form of the theory, when the assumed disturbances of the gaseous fluid occasioning the effect called sound were supposed to be of the same kind as, or to be analogous to, these progressive undulations in water called waves; at a later period it was found that the disturbances or undulations in the elastic fluid, which produced the *sound-phenomena*, differed essentially in character from the waves of the liquid (water); consequently the theory underwent some modification, which included the substitution of the term undulatory for that of wave-theory.

Lardner's Natural Philosophy. Undulation of Liquids.

(800.) "*Stationary waves explained*:—Hence it appears that each of the particles composing the surface of a liquid is affected by an alternate vertical motion. This motion, however, not being simultaneous but successive, an effect will be produced on the surface which will be attended with the form of a wave, and such wave will be progressive. The alternate vertical motion by which the particles of the liquid are affected will however sometimes take place under such conditions as to produce not a progressive but a stationary undulation. This would be the case if all the particles composing the surface were simultaneously moved upwards and downwards in the same direction, their spaces varying in magnitude according to their distance from a fixed point. To explain this, let us suppose the particles of the surface of a liquid between the point *a. e.* Fig. 234, (Pl. 1) to be simultaneously moved in vertical lines upwards, the centre particle *c.* being raised through a greater space than the particles contiguous to it on either side. The heights to which the other succeeding particles are raised will be continually diminishing, so that at the end of a second the particles of liquid which, when at rest, formed the surface *a. e.* will form the curved surface *a. b. c. d. e.* In like manner, suppose the particles of the surface *e. i.* to be depressed in vertical lines corresponding exactly with those through which the particles *a. e.* were elevated. Then the particles which originally formed the surface *e. i.* would form the curved surface *e. f. g. h. i.*" and they would become the depression of a wave. Thus the elevation of the wave would be *a. b. c. d. e.*, and its depression *e. f. g. h. i.*

Having attained this form, the particles of the surface *a. b. c. d. e.* would fall in vertical lines to their primitive level, and having attained that point, would descend below it; while the particles *e. f. g. h. i.* would rise to their primitive level, and, having attained that position, would continue to rise above it. In fine, the particles which originally formed the surface of the undulation *a. b. c. d. e. f. g. h. i.* would ultimately form the surface *a.' b.' c.' d.' e.' f.' g.' h.' i.'* represented by the dotted line. Having attained this form, the particles would again return to their primitive level, and would pass beyond it, and so on alternately. In this case therefore, there would be an undulation, but not a progressive one. The nodal points would be *a. e. i. n. r.* and these points, during the undulation, would not be moved; they would neither sink nor rise, the undulatory motion affecting only those between them. This phenomenon of a stationary undulation produced on the surface of a liquid may easily be explained, by two systems of progressive undulation meeting each other under certain conditions, and producing at the points we have here called nodal points the phenomenon of interference, which we shall presently explain."

802. "*Depth to which the effect of waves extend.*—When a system of waves is produced upon the surface of a liquid by any disturbing force a question arises to what depth in the liquid this disturbance in the equilibrium extends. It is possible to suppose a stratum of the liquid at any supposed depth below which the vertical derangement would not be continued. Such a stratum would operate as the bottom of the agitated part of the fluid.

The Messrs. Webber, to whose experimental inquiries in this department of physics, science is much indebted, have ascertained that

From Lardner's Natural Philosophy.

PLATE I.

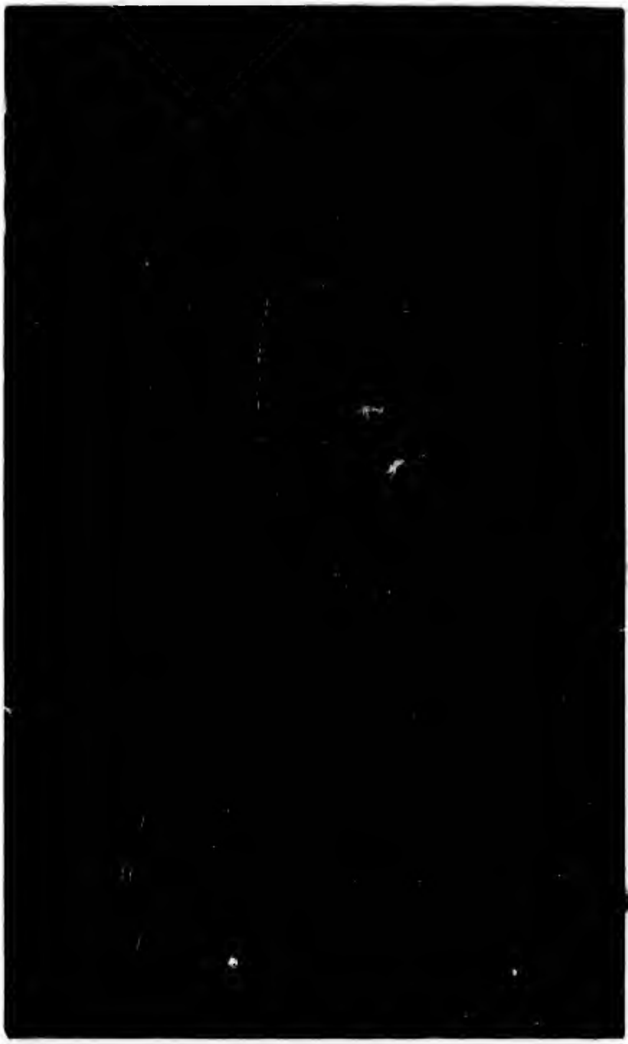

Fig. 235

Fig. 234

The Form and Reflection of Waves.

the equilibrium of the liquid is not disturbed to a greater depth than about three hundred and fifty times the altitude of the wave."

804. "*Law of reflection—angles of incidence aud reflection equal.* The angle *C. N. Q.* is called *the angle of incidence* of the wave, and the angle *Q. N. R.* is called the *angle of reflection;* and hence it is established as a general law, that in the reflection of waves from any obstructing surface, the angle of incidence is equal to the angle of reflection, a law which has been already shown to prevail when a perfectly elastic body is reflected by a perfectly hard surface. When a wave strikes a curved surface, it will be reflected from it in a different direction, according to the point of the surface at which it is incident. It will be reflected from such point in the same direction as it would be if it struck a plane which coincides with the curved surface at this point."

809. "*Phenomena produced when two systems of waves encounter each other.*—When two waves which proceed from different centres encounter each other, effects ensue which are of considerable importance in those branches of physics whose theory is founded upon the principles of undulation.

I. If the elevation of one wave coincides with the elevation of another, and the depressions also coincide, a wave would be produced, the height of whose elevation, and the depth of whose depression, will be equal to the sum of the heights and depths of the elevation and depression of the two waves which are thus, as it were, superposed. *

II. If, however, the elevation of one wave coincide with the impression of the other, and *vice versâ,* then the effect will be a wave whose elevation will be equal to the difference of the elevation, and whose depression will be the difference of the depression of the two waves which thus meet.

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* Note.—Nos. I. and III, of the above propositions are open to objection, and inadmissible unless strictly demonstrated. The probable effect (of such *superposition*) would be to increase the volume of, and to amplify the wave in breadth, and to increase the rapidity of its propagation (or velocity of the undulation) but not to increase its elevation and depression. The mean point of distance between the maximum elevation and depression must be the plane (i. e., mean horizontal plane) of the liquid. It certainly requires demonstration that the elevation and depression of one wave can be increased by the addition or coincidence of a second wave, of which the elevation and depression is not greater than that of the first.

III. If, in the former case, the heights and depressions of the waves superposed be equal, the resulting wave will have double the height of the elevation, and double the depth of the depression.

IV. If the heights and depressions be equal in the second case, the two waves will mutually destroy each other, and no undulation will take place at the point in question; for the difference of elevations and the difference of depressions being nothing, there will be neither elevation nor depression. In fact, in this latter case, the depression of each wave is filled up by the elevation of the other."

810. "*Interference of waves.*—This phenomenon, involving the effacement of an undulation by the circumstance of two waves meeting in the manner described, is called, in the theory of undulation, an interference, and is attended with remarkable consequences in several branches of physics."

811. "*Experimental illustration of it.*—The two systems of waves formed by an elliptical surface, and propagated, one directly around one of the foci, and the other formed by reflection around the other, exhibit in a very beautiful manner, the phenomena not only of reflection, as has been already explained, but also of interference as has been shown with remarkable elegance by the Messers. Webber already referred to. These phenomena are represented in Fig. 240, Pl.3, where *a.* and *b.* are the two foci. The strongly marked circles indicate the elevation of the waves formed around each focus, and the more lightly traced circles indicate their depression. The points where the strongly marked circles intersect the more faintly marked circles, being points where an elevation coincides with a depression, are consequently points of interference, according to what has been just explained. The series of these points form lines of interference, which are marked in the diagram by the dotted lines, and which, as will be seen, have the forms of ellipses and parabolas round the same foci."

812. "*Inflection of waves.*—If a series of waves encounter a solid surface in which there is an opening through which the waves may be admitted, the series will be continued inside the opening and without interruption; but other series of progressive waves having a circular form will be generated, having the edge of the opening as their centres.

Let *M.* *N.*, Fig. 241, Pl. 3, represent such a surface, having an opening whose edges are *A.* and *B.*, and let *C.* be a centre from which a series of progressive circular waves is propagated. These waves, *From Lardner's Natural Philosophy.*

PLATE III.

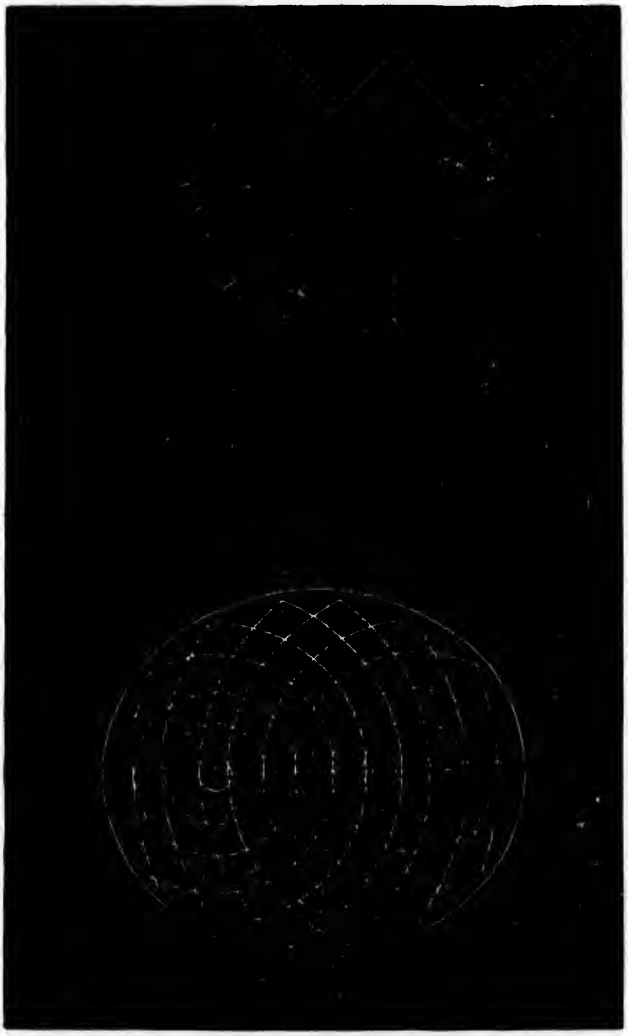

Fig 241

Fig. 240

Interference and Inflexion of Waves.

entering at the opening *A. B.*, will continue their course uninterrupted forming the circular arcs *D. E.* But around *A.* and *B.* as centres, systems of progressive circular waves will be formed which will unite with the waves *D.E.*, completing them by circular arcs *D.F.* and *E.F.* meeting the obstructive surface on the outside; but these circular waves will also be formed throughout the remainder of their extent, as indicated in the figure, on both sides of the obstructing surface, and intersecting the original system of waves propagated from the centre *C.* They will also form with these, series of points of interference according to the principles already explained.

The effects here described as produced by the edges of an opening through which a series of waves is transmitted is called inflection, and it will appear hereafter that they form an important feature in several branches of physics whose theory is based upon the principles of undulation."

Quotation from *Lardner's Natural Philosophy*, continued:—

Undulation of Elastic Fluids.

"If any portion of the atmosphere, or any other elastic fluid diffused through space, be suddenly compressed and immediately relieved from the compressing force it will expand in virtue of its elasticity, and, like all other similar examples already given, will, after its expansion, exceed its former volume to a certain limited extent, after which it will again contract, and thus oscillate alternately on the one side and on the other of its position of repose.

814. "*Undulations of a sphere of air.*—We may consider this effect to be produced upon a small sphere of air having any proposed radius, as, for example, an inch. Let us suppose that it is suddenly compressed so as to form a sphere of half an inch in radius, and being relieved from the compressing force it expands again, and surpassing its former dimensions swells into a sphere of an inch and a half. It will again contract and return to the magnitude of a sphere, with a radius somewhat greater than half an inch, and will again expand and so oscillate, forming alternately spheres with radii less and greater than an inch, until at length the oscillation ceases, and it resumes permanently its original dimensions.

These oscillations will not be confined to the single sphere of air in which they commenced; the circumambient air will necessarily follow the contracting sphere when first compressed, so that a spherical shell of air which lies outside the sphere will expand and become less dense than in its state of equilibrium.

When the central sphere again expands, this external spherical shell will contract, and will become more dense than in its state of equilibrium. This shell will act in a similar manner upon another spherical shell outside it, and this upon another outside it, and so forth. If then we suppose a number of successive spheres surrounding the point of original compression, we shall have a series of spherical shells of air, which will be alternately condensed and expanded in a greater degree than when in a state of repose. This condensation and expansion thus spreading spherically round the original centre of disturbance, is in all respects analogous to a series of circular waves forming round the central point upon the surface of a liquid, the elevation of the wave in the case of the liquid corresponding to the condensation in the case of the gas, and the depression of the wave corresponding to the expansion of the gas."

815. "*Analysis of the propagation of an undulation through an elastic fluid.*—We will limit our observations in the first instance to a single series of particles of air, expanding in a straight line from the centre of disturbance *A.*, Fig. 242, towards *T.* Let *S. A.* represent the space through which the disturbing force acts, and let us imagine this air suddenly pressed from *S.* to *A.* by some solid surface moving against it, and let us suppose that this motion from *S.* to *A.* is made in a second. Now, if air were a body devoid of elasticity, and like a perfectly rigid rod, the effect of this motion of the solid surface from *S.* to *A.* would be to push the remote extremity *T.* through a space to the right corresponding with and equal to *S. A.*

But such an effect does not take place, first, because air is highly elastic, and has a tendency to yield to the force excited by the solid surface upon it while it moves from *S.* to *A.*; and secondly, because to transmit any effect from *A.* to a remote point, such as *T.*, would require a much greater interval of time than that which elapses during the movement of the surface from *S.* to *A.* The effect, therefore, of the compression, in the interval of time which elapses during the motion from *S.* to *A.*, is to displace the particles of air which lie at a certain definite distance to the right of *A.* Let this distance for example be *A. B.* All the particles, therefore, of air which lie in succession from *A.* to *B.* will be effected more or less by the compression, and will consequently be brought into closer contiguity with each other; but they will not be equally compressed, because to enable the series of particles of air lying between *A.* and *B.* to assume a uniform density requires a longer time than elapses during the motion of the solid surface from *S.* to *A.* At the instant, therefore, of the arrival of the compressing surface at *A.* the line of particles between *A.* and *B.* will be at different distances from each other; and it is proved by mathematical principles, that the point where they are most closely compressed is the middle point *m.* between *A.* and *B.* and therefore, departing from the middle point *m.* in either direction, they are less and less compressed. The condition, therefore, of the air between *A.* and *B.* is as follows. Its density gradually increases from *A.* to *m.* and gradually decreases from *m.* to *B.* Now, it is also proved that the effect of the elastic force of the air is such that, at the next moment of time after the arrival of the compressing surface at *A* the state of varying compression which has just been described as prevailing between *A.* and *B.* will prevail between another point in advance of *A.* such as *A'.* and a point *B'.* equally in advance of *B.*, and the point of the greatest compression will, in like manner, have advanced to *m'.* at the same distance to the right of *m.* In short, the conditions of the air between *A'.* and *B'.* will be in all respects similar to its condition the previous moment between *A.* and *B.*, and in like manner, in the next moment, the same condition will prevail between the particles *A''.* and *B''.* to the right of *A'.* and *B'.* Now, it must be observed that as this state of varying density prevails from left to right, the air behind it, in which it formerly prevailed, resumes its primitive condition. In a word, the state of varying density which has been described as prevailing between *A.* and *B.* at the moment the compressing surface arrived at *A.* will in the succeeding moments, advance from left to right towards *T.*, and will so advance at a uniform rate; the distance between the points *A. B. A'. B'.* and *A''. B''.*, &c., always remaining the same."

816. "*Aerial undulations.*—This interval between the points *A.* and *B.* is called a *wave* or *undulation*, from its analogy, not only in form but in its progressive motion, to the waves formed on the surface of liquids, already described: the difference being that in the one case the centre of the wave is the point of greatest elevation of the

surface of the liquid, and in the other case it is the point of greatest condensation or compression of the particles of the air. The distance between *A.* and *B.* or between *A'.* and *B'.* or between *A''.* and *B''.*, which always remains the same as the wave progresses, is called the *length of the wave.*

In what precedes we have supposed the compressing surface to advance from *S.* to *A.* and to produce a compression of the air in advance of it. Let us now suppose this surface to be at *A.*, the air contiguous to it having its natural density.

If the wave *proceed contrariwise* from *A.* to *S.* the air which was contiguous to it at *A.* will rush after it in virtue of its elasticity, so that the air to the right of *A.* will be disturbed and rendered less dense than previously. An effect will be produced, in fine, precisely contrary to that which was produced when the wave advanced from *S.* to *A.*; the consequence of which will be that a change will be made upon the air between *A.* and *B.* exactly the reverse of that which was previously made, that is to say, the middle point *m.* will be that at which the rarefaction will be greatest, and the density will increase gradually, proceeding from the point *m.* in either direction towards the points *A.* and *B.* The same observations as to the progressive motion will be applicable as before, only that the progression *m.* instead of being the point of greatest condensation, will be the point of least density."

817. "*Waves condensed and rarefied.*—The space *A. B.* is also in this case denominated a wave or undulation. But these two species of waves are distinguished one from the other by being denominated, the former a *condensed,* and the latter a *rarefied wave.* Now, let it be supposed that the compressing surface moves alternately backwards and forwards between *S.* and *A.* making the excursions in equal times. The two series of waves, as already defined, will be produced in succession. While the condensed wave moves from *S.* towards *T.* the rarefied wave immediately follows it, and in the same manner this rarefied wave will be followed by another condensed wave, produced by the next oscillation, and so on. The analogy of these phenomena to the progressive undulation on the surface of a liquid, as already described, is obvious and striking.

What has been here described with reference to a single line of particles extending from the centre of the distance *A.* in a particular direction, is equally applicable to every line diverging in every conceivable direction around such centre, and hence it follows that the succession of condensed and rarefied waves will be propagated round the centre, each wave forming a spherical surface, which is continually progressive and uniformly enlarges, the wave moving from the common centre with a uniform motion."

818. " *Velocity and force of Aerial waves.*—The velocity with which such undulations are propagated through the atmosphere depends on, and varies with, the elasticity of the fluid.

The degree of compression of the wave which corresponds to the height of a wave in the case of liquids, depends on the energy of the disturbing force. All the effects which have been described in the case of waves formed upon the surface of a liquid are reproduced, under analogous conditions, in the case of undulations propagated through the atmosphere."

819. " *Their interference.*—Thus, if two series of waves coincide as to their points of greatest and least condensation, a series will be formed whose greatest condensation and rarefaction is determined by the sum of points, as prevailing in the separate undulations;* and if the two series are so arranged that the points of greatest condensation of the one coincide with the greatest rarefaction of the other, and, *vice versâ*, the series will have condensations and rarefactions determined by the difference of each of the separate series; and, in fine, if in this latter case the condensations and rarefactions be equal, the undulations will mutually efface each other, and the phenomena of interference, already described as to liquids, will be reproduced.

As the undulations produced in the air are spread over spherical surfaces having the centre of disturbance as a common centre, the magnitude of these surfaces will be in the ratio of the squares of the radii, or what is the same, of the squares of their distances from the point of central disturbance; and as the intensity of the wave is diminished

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* See the note at page 95. Assuming that the soundness of the objection stated in that note has to be allowed, it is not perhaps quite so obvious that it will also apply to the case above. We opine, however, that (assuming the possibility of an aerial wave such as described) the two cases are, in respect to this particular, strictly analogous, and that, consequently, the same objection does apply; namely, that the coincidence of two undulations (or waves) in the elastic fluid will not increase the condensation and rarefaction as stated above but will increase the amplitude and wave length of the undulation.

in proportion to the space over which it is diffused, it follows that the effects or energy of these waves will diminish as the squares of their distances from the centre of propagation increase."

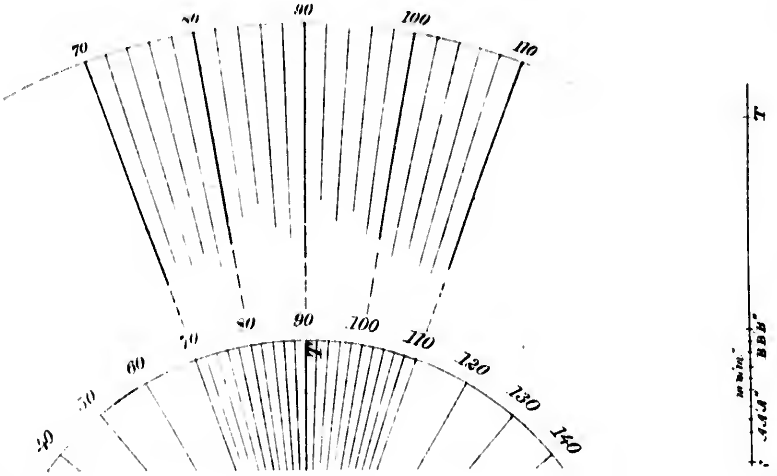
It appears to us that certain of the propositions relating to interference in the (liquid) wave theory, as stated in the preceding quotation, are not sufficiently supported by experimental demonstration and are by no means satisfactorily established. In the four cases, stated art. 809, of two systems of waves encountering each other, it seems most probable that, whether the elevations and depressions of the one coincide with those of the other or whether they do not coincide, the two waves will destroy or neutralize each other; and, moreover, it seems probable that such neutralization would take place immediately in the case where the elevation of the one coincided with the elevation of the other, * (but this is directly the contrary to Dr. Lardner's statement in the preceding quotation), whereas if the elevation of the one coincided with the depression of the other, the one would probably pass over and under the other, and both would continue to undulate in the opposite directions for a limited distance and only gradually destroy each other by an interference which might be called frictional. The propositions would, as it seems to us, apply more correctly to two systems of waves travelling (or propagated) in the same direction, the undulations of the one having a greater velocity than, and overtaking, the other. (It is on the assumption of an actual interference of the kind supposed that the objection to the particular case contain-

* If, however, the elevation and depression of the encountering waves be considerable, both waves would be partially reflected, and this reflection would be more complete the greater the velocity of the encountering waves.

ed in the note at p. 16 is made, and we are not to be understood thereby as affirming or admitting the soundness of any part of the general theory to which these propositions belong.) But the same propositions are applied, Art. 819, to interference of encountering undulations in elastic fluids; and it is, as appears, at once assumed, on the ground of analogy only, that these propositions are to be accepted as (fact) postulates or axioms. But the objection taken to them in their application to the liquid wave also applies, and even more obviously, to the encountering undulations of the elastic fluid. If two equal undulations encounter from opposite directions it seems almost obvious either that they most destroy (neutralize) each other, or that both of them must be reflected; but Nos. I. and III. of the propositions, applied to elastic fluids in Art. 819, teach that in such case, the effect (in the compression and rarefaction of the resulting undulation) is the sum of the two undulations; without defining, however, in which direction the resulting undulation or wave is to proceed. In the case of proposition II., where the resulting wave or undulation is stated to be the difference of the two, the doctrine does not appear so incredible—although, in this case, the result which anyone acquainted with the laws and phenomena belonging to mechanical science would probably expect to find, would be a velocity in the resulting wave or undulation equal to the *difference* in the *velocities* of the encountering unequal undulations.

However, the entire theory in its application to elastic fluids, as set forth, is quite at variance with the known facts and established laws of mechanical science. What should be our answer if called upon to admit that a pound of water in descending one foot could develope or eliminate mechanical power capable of raising a ton weight of water not only to a height of one foot but to a height of an unlimited or indefinite number of miles? Yet such assumption is substantially contained in the doctrine here set forth. Referring to the illustration, Fig. 242, "let *S. A.* represent the space through which the disturbing force acts, and let us imagine this air suddenly pressed from *S.* to *A.* by some solid surface moving against it, and let us suppose that this motion from *S.* to *A.* is made in a second." Herein we have clearly stated the definite exciting or developing cause of a definite quantity of mechanical force or power, because a definite amount of compression in a definite time of a definite quantity of air (or other elastic fluid) represents a definite amount of mechanical power just as certainly as the descent of a definite weight from a definite height, or the motion of a definite weight through a definite space in a definite time. And what is the effect which we are told this definite amount of mechanical force or power is capable of performing? In order to understand this clearly, let us, with the same figure, (Fig. 242,) take the point *A.* as a centre and (in Fig. 1) with the distance *A. T.* describe the circle *T. U. V. Y.*; now let us suppose that the wave-undulation, as represented, has a volume the breadth of which when it has reached the point *T.* will be equal to one degree of the circle. We are told at the end of Art. 817, that the effect defined and illustrated in respect to the one direct line "is equally applicable to every line diverging in every conceivable direction around such centre." By the illustration and statement the result or effect at the point *T.* in the one direct line, the volume

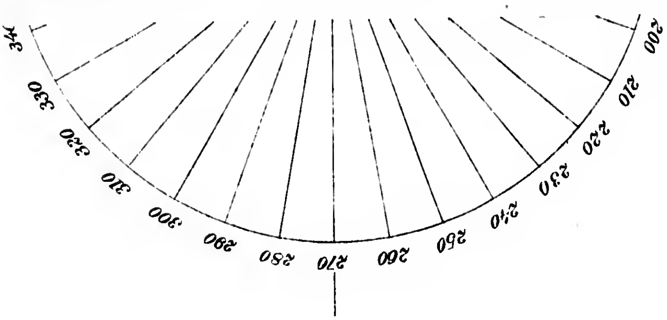
Fig 1.



CENTRIFUGAL FORCE AND GRAVITATION.

Part Fifth.

Correction—page 104, the 22nd and 23rd lines.
For...'the point *A.*' And, for...'the distance *A.T.*'
Read...the point *S.* And...the distance *S.T.*



of water in descending one foot could develope or eliminate mechanical power capable of raising a ton weight of water not only to a height of one foot but to a height of an unlimited or indefinite number of miles? Yet such assumption is substantially contained in the doctrine here set forth. Referring to the illustration, Fig. 242, "let *S. A.* represent the space through which the disturbing force acts, and let us imagine this air suddenly pressed from *S.* to *A.* by some solid surface moving against it, and let us suppose that this motion from *S.* to *A.* is made in a second." Herein we have clearly stated the definite exciting or developing cause of a definite quantity of mechanical force or power, because a definite amount of compression in a definite time of a definite quantity of

Fig 1.

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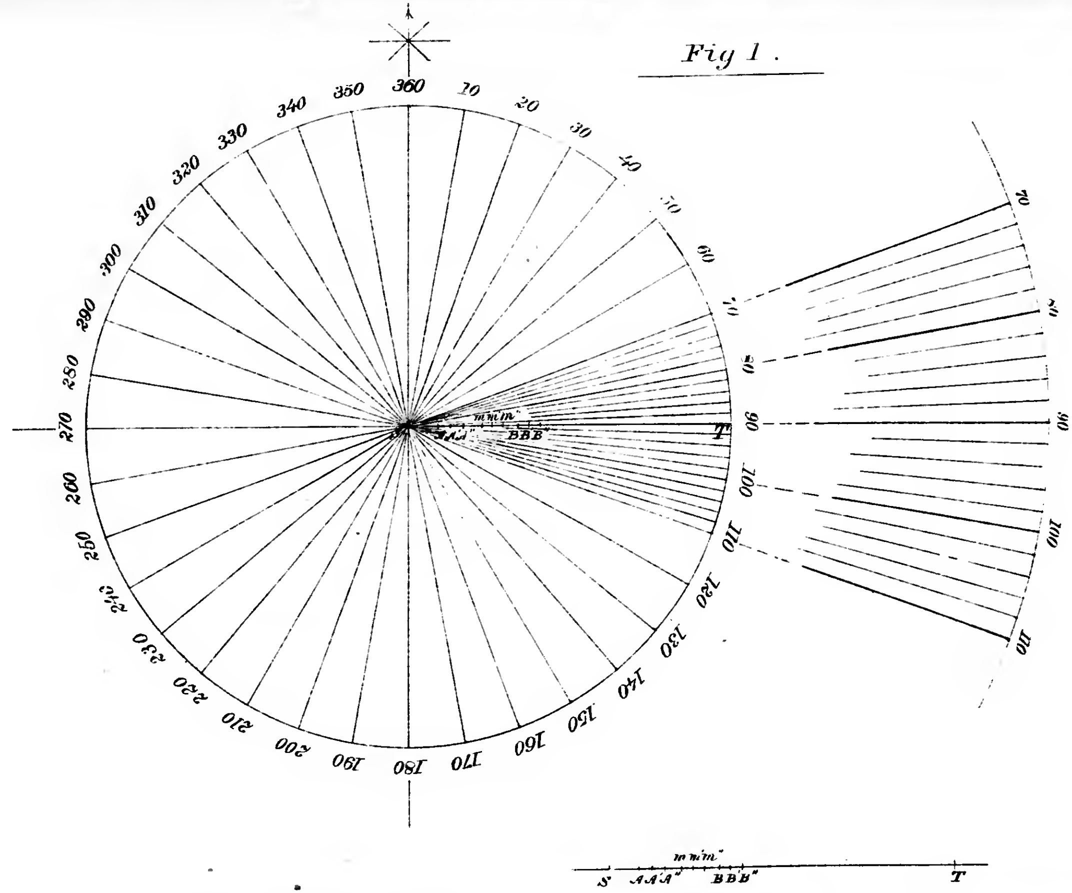
Fig 1.



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of compressed fluid being the same, represents the whole of the mechanical power, developed in the compression from *S.* to *A.**; but the circle *T. U. V. Y.* contains 360 degrees of which the line terminating at *T.* only represents one, consequently if the effect is transmitted in undiminished quantity to every point in the circle, the original effect has been increased 360 times. Now, if in place of the circle we suppose a sphere, the square of this quantity, namely, 360 × 360, will represent the increase in the effect. We can, however, as an argument, if any difficulty is felt as to this preliminary increase, afford to leave this aside, and to suppose a circle or sphere of any definite small size to represent the original definite quantity of mechanical power eliminated. Then, if a circle and the distance from the central point is doubled, the area or areal content of the larger circle will equal the square of the areal content of the lesser circle; or if a sphere and the distance from the central point is so doubled, then will the cube of the volume of the lesser sphere represent the volume (content) of the greater. Therefore, since the effect as illustrated in the one line is "equally applicable to every line diverging in every conceivable direction around such centre," it follows that, when the distance from that centre is for the first time doubled, the effect (which is assumed to be transmitted in undiminished energy and amount to every part of the surface of the surrounding sphere) must have increased in cubical proportion, *i.e.*, representing the original effect, or definite amount of power eliminated,

*This may be made more clearly apparent by supposing the line S. T., in the illustration Fig. 242, to represent a tube of any definite size.

by $P.$, we now have at the surface of the duplicated sphere ..P^3. When this greater sphere is again duplicated, by increasing the radial distance in every direction, to four times $A. T.$, then the first resulting effect must be again cubed, and we obtain..P^6. At the next duplication .. P^9, and so on. That the effective energy, in any one direction, of the mechanical power developed or eliminated by the primary compression must diminish as the distance from the originating point increases, is to a certain extent admitted at the end of Art. 819, where it is thus stated: "As the undulations produced in the air are spread over spherical surfaces having the centre of disturbance as a common centre, the magnitude of those surfaces will be in the ratio of the squares of their radii, or what is the same, of the squares of their distances from the point of central disturbance; and as the intensity of the wave is diminished in proportion to the space over which it is diffused, it follows that the effects or energy of these waves will diminish as the squares of their distances from the centre of propagation increase."

The diminution of energy, in the case supposed, would be, not as the squares of the radial distances, but as the cubes of those distances; because the increase is as the increasing volumes of the spheres, through which increasing volumes the undulation has to be propagated; the undulation is not simply spread *out into the surface* of the greater sphere, but has to travel *throughout the volume* of the greater sphere.

Note. This objection, viz., that the amplification, and consequent diminution of intensity, must be as the cube instead of as the square of the increasing distance, stands by itself.*

As a mere verbal argument, we are aware that an answer may be given which to some supporters of the undulatory theory might appear sufficient, namely, that the undulations once commenced are not supposed to increase in wave-length, nor to diminish directly in longitudinal intensity; *i. e.* that if it were not for the lateral increase in amplitude (lateral extension) the wave impulse might be propagated to an unlimited distance without diminution of intensity. But this assumption is not, as it seems to us, compatible with the fundamental origin and character of the wave impulse as set forth; it is not anywhere shown how a definite quantity of mechanical power eliminated, being contained in and propagated by the alternate

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* If the primary sphere of compressed air, (or ether), which forms the originating centre of the undulation be supposed to retain its individuality as a sphere and to propagate itself radially (if we can conceive it) in every direction, it is obvious that it must overcome the negative resistance, *vis inertiæ*, of the particles of air (or of ether), to its progress in each and every direction, and this resistance would increase as the cube of the distance from the originating centre. It is just as evident that by Lardner's hypothesis (quoted page 19) of the alternatively expanding and contracting spheres, all the particles of air (or ether), occupying space between the centre and the surface of the outermost sphere, have to be set in motion. We shall presently point out that the supposition of the spherical shells of elastic fluid, one outside another, propagating a limited and definite quantity of mechanical power, as stated by Lardner (quotation page 19), involves the necessary absurdity of supposing expansion and contraction in the volume of the air or ether (elastic fluid) to take place at one and the same time, because compression here means contraction in volume, and expansion in volume must be continuous for the volume of the lesser sphere to continually increase into the greater sphere surrounding it.

expansion and contraction of a definite spherical portion of elastic fluid, can be amplified laterally without being also amplified longitudinally. It is true, in the impact theory propounded in the Encyc. Brit.* by which the particles are supposed to transmit the impulse in a straight line in one direction only, the objection would not apply, but then it is not shown how that theory, or that form of the undulatory theory, is to be applied to an influence which extends itself radially from a centre in all directions; the writer of the Art., indeed, when the application of the theory to the actual circumstances has to be considered, appears to entertain a misgiving as to the tenability of the theory, a misgiving expressed in the sentence "expanding continually, if we can conceive it, into a wider and wider concentric sphere." Now persons do not feel a difficulty in conceiving known facts as facts, the observation or recognition of the fact supplies (stands in the place of) the conception so far, but, when it is proposed to account for the fact according to a particular theory, and there is a difficulty in conceiving the fact in the proposed connection with the theory, it must then be the theory, and not the fact itself, which occasions the difficulty; for example, it being known as a fact that the impulse causing sound, having originated at a central point, spreads or extends itself spherically (radially) from that point in all directions, there is no difficulty in conceiving it to be so, but taking the fact in connection with the theory proposed the proviso becomes necessary "if we can conceive it."

Whether, however, the diminution be considered proportional to the cube or to the square of the distance,

* See quotation, page 110.

the admission thereof must be alike fatal to the theory,* as it is set forth in articles 815, 816, 817. The case supposed is that of alternate compression and expansion, of condensation and rarefaction; but if it be admitted that the energy diminishes because the undulation has to occupy a greater magnitude, then it follows that the matter of which the undulation consists must expand so as to occupy that greater magnitude, and it becomes impossible to conceive a compression to take place of its particles of matter into a smaller space which are at the same time expanding into a greater space. . . We are called upon to suppose the definite quantity of matter, of which the undulation consists, to be undergoing condensation and to be expanding at one and the same time.

In reference to the explanations and comparison of the phenomena belonging to the wave undulations of liquids, and to the supposed undulations of elastic fluids, contained in the preceding quotation from Lardner's Natural Philosophy, it may be remarked that the agreement or analogy between them is of that kind which exists, more or less, between all sorts of vibrations and oscillations; and the disagreement or distinctive difference in character, is that, in the one, gravitation is the agent in propagating the impulse, and in the other, the elastic property and compressibility of the fluid allows the supposed

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* In reference to this (unavoidable) admission, we would suggest a question.... What must have been the original intensity of a wave or undulation of solar-light which has come to us from a distance of 95 million miles, and which has been (by the admission) diminishing in intensity, as the square of the increasing distance from the centre of propagation (*i. e.* the sun)?

alternate contraction and expansion arising from the impulse to propagate the effect.

That the undulations in the elastic fluid, assuming that such may be propagated in the manner supposed and that they result in the effect called sound, are in fact of an entirely distinct nature from the liquid wave, is quite evident, because it is known that sound may be transmitted to a great distance through water without interruption or interference from the liquid undulations and oscillations of the wave character, which may be taking place at the same time therein. The particular character of the vibrations in the elastic medium which are supposed to propagate the disturbing impulse and to result in that effect known as sound is thus explained in the Art. *Acoustics of the Encyclopedia Britannica.*

"In order to conceive the mode in which sound is propagated through the air, let us consider what takes place when we move a series of balls ranged in a line on a table, or suspended by threads. If we strike the one end of the line by impelling a ball against it, it is only the ball at the other end which appears to be affected. This flies off from the rest, and leaves them almost stationary. The intermediate balls, therefore, serve merely to transmit the impulse from the one end to the other of the series. In the same manner it is that the agitation or impulse, from which sound arises, is transmitted through the air. This fluid, like every other body, consists in an infinite number of little particles; a single series of which may be represented to us by the balls in the above example. These particles are not even in contact with each other; they are separated by minute intervals, but are yet connected together by attractive and repulsive forces, which tend to retain them perpetually in equilibrium. In every case, therefore, there is in reality a chain of such particles reaching from the sounding body to the ear. The former, by its agitation, strikes that particle which is next to it, the intermediate ones serve to convey the impression, and the last one, flying off, strikes the sentient organ of hearing. The process is exactly similar to that of impulse along a series of balls, only that in the case of the air, the intermediate particles, instead of remaining at rest, move each of them backwards and forwards by a very minute interval; the first communicating its motion to the second, the second to the third, and so on to the last; each performing a slight oscillatory movement, which advances from the beginning to the end of the series. We now see at once the cause of a remarkable and well-known fact, that the propagation of sound is not instantaneous; it requires time to advance from the sounding body to the ear, as is daily observed and illustrated in the discharge of fire-arms. If the distance be at all considerable, a sensible interval is always observed to elapse between the flash and the report. The light flies almost instantaneously, but the report is retarded acccording to the distance; as is also seen in other cases: when we observe the workmen, for example, cutting up large stones in any quarry; if we stand at a little distance, we see invariably and distinctly the blow of the hammer on the stone before the sound reaches the ear. These and other similar facts leave no doubt that sound advances only at a certain rate, and invariably requires time for its propagation; and the reason is, that each aërial particle in the chain of communication must have a certain time, minute no doubt, "but still definite, to perform its oscillation, and communicate its motion to the rest; and thus the advance of the agitation and of the sound is retarded; and only sweeps with a regulated progression along the line. It is not through one series of particles merely that the oscillatory motion is communicated. The sounding body, having every part of it in a state of agitation, generally acts all round; but, even though it were only to act in one direction, the impulse, once begun at the centre, is propagated in all directions; for though only one particle were originally affected, so intimately were they all connected together and united into a system by their mutual attractions and repulsions, that this cannot advance in any degree forwards without affecting the particles on each side; these affect what are before and around them; and thus the impulse is communicated, and diffuses itself on all sides. These lateral impressions would appear to be necessarily somewhat enfeebled, yet it is one remarkable characteristic of such oscillatory movements, that, like the vibrations of a distended cord, or the oscillations of a pendulum in a cycloid, they are all performed in the same time, however minute or however extended. The lateral impressions, therefore, though ever so feeble, are yet transmitted with the same rapidity as the direct; the sound may be weakened, and we often observe it is so; a speaker, for example, is always best heard in front; the report of a cannon is also loudest in that direction, but still the sound is heard at the very same instant all around. It is owing to this diffusion of the agitation in all directions, the original impression being spread out, not merely in concentric circles like the waves in a pool, but expanding continually, if we can conceive it, into a wider and wider concentric sphere,—it is owing to this that every sound decreases so rapidly as we recede from it, and at last dies away in the distance."

The theory of the transmission of the sonorous impulse as thus defined by the writer in the Encyclopedia Britannica differs very much from the teaching of Lardner. The wave analogy, and the alternate compression and rarefaction of the elastic fluid, are, apparently, herein discarded, and the transmission is explained to consist in the communication of motion from one particle to the next by contact or impact. This hypothesis is much more simple, and is not in some respects so obviously objectionable as that stated by Lardner; but it does not explain some, and is irreconcileable with other particulars of the observed facts; for example, it is not explained how the phenomena of interference are to be accounted for under this hypothesis. The impact-communication, and transmission of the impulse from particle to particle, is supposed to apply also and in like manner to liquids and to such solids as are capable of transmitting sound. Notwithstanding the inelasticity of water, it is found to be a good conductor of sound. "It appears from the experiments of M. Calloden, at Geneva, that sounds are transmitted through the water to great distances with greater force than through air. A blow struck under the water of the Lake of Geneva was distinctly heard across the whole breadth of the Lake, a distance of nine miles."

We may here take the opportunity, also, to remark the hypothetical definitions contained in the several terms used by teachers to denote the impulses in connection with the partial explanations which frequently accompany their use, e.g., un-

dulations, waves, vibrations, wave-lengths of the vibrations, or of the oscillations, longitudinal oscillating motions of the particles of ether; transverse oscillating motions of the particles of ether, &c. . . . we would suggest whether a careful examination might not show that herein we have an attempt to combine together the discordant elements of two or three distinct theories, neither of which will bear to be distinctly stated and examined separately on its own merits. Hence a general mystification and vagueness which assists to increase the apparent abstruseness and prof[illegible]ity of the subject. Nothing, we may safely say, is m[illegible] be distrusted in a sound scientific sense, than a theory which will not bear to be definitely and distinctly stated, and which, in its most simple and general application becomes unintelligible.

A liquid wave is superficial and dependent upon gravitation, under the influence of which, the mobility of the particles of liquid admitting of such effect, the descent of certain particles causes the ascent of an equal number; the vertical deviation (height and depth of the wave) being confined to a limited distance above and below the horizontal surface of the liquid. In the vibration of a string, the extent of the deviations from the straight line contained between the two extremities of the string (i.e. of the vibration) is confined to a very limited distance by the molecular cohesion (or mutual attraction of the particles). In each of these cases the result is the intelligible effect of a recognized cause; but in the hypothetical alternate expansions and contractions of a certain small portion of an elastic fluid, propagating itself through the bulk of that fluid to great distances, and keeping itself distinct therefrom, we have an unintelligible supposition, or an arbitrary and unreasonable assumption, because no *intelligible cause can be assigned for the supposed limitation of the effect, When the expansion commences why does it not continue? What is there to determine a limit? Let, for example, a small quantity of compressed ether be injected into space, what is there to prevent the continued and unimpeded expansion of that small quantity until it becomes as attenuated as that which surrounds it? Why should it expand and contract alternately? Or, if the particles of ether are supposed to oscillate and to make excursions to and fro; why should they so oscillate? Having commenced to move in the one direction, what is there to impede the continuous motion of the particles in that direction? What fact or natural law is there to support and render intelligible the assumption?*

The following quotation from *Lardner's Natural Philosophy* contains the notice of certain of the observed facts belonging, more particularly, to the science of Acoustics.

821. "*Presence of air necessary to the production of sound.*—That the presence of air or other conducting medium is indispensable for the production of sound, is proved by the following experiment.

Let a small apparatus called an alarum, consisting of a bell, the tongue of which is governed by a string, be placed under the receiver of an air pump, through the top of which a rod slides, air-tight, the end of the rod being connected with a detent which governs the motion of the tongue through the intervention of the string. This rod can by a handle placed outside the receiver be made to disengage the string, so as to make the bell within it ring whenever it is desired. This arrangement being made, and the alarum being placed outside the receiver, upon a soft cushion of wool, so as to prevent the vibration from being communicated to the pump-plate, let the receiver be exhausted in the usual way. When the air has been withdrawn, let the bell be made to ring by means of the sliding rod. No sound will be heard, although the percussion of the tongue upon the bell, and the vibration of the bell itself are visible.

Now if a little air be admitted into the receiver a faint sound will begin to be heard, and the sound will become gradually louder in proportion as the air is gradually readmitted.

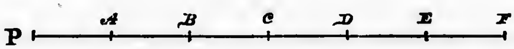
In this case the vibrations which distinctly act upon the ear are not those of the air contained in the receiver. These latter act upon the receiver itself and the pump-plate, producing in them sympathetic vibration; and those vibrations impart vibrations to the external air which are transmitted to the ear.

If in the preceding experiment a cushion had not been interposed between the alarum and the pump-plate, the sound of the bell would have been audible, notwithstanding the absence of air from the receiver.

"The vibration in this case would have been propagated, first from the bell to the pump-plate and the bodies in contact with it, and thence to the external air."

822. "*A continuous body of air not necessary.*—Persons shut up in a close room are sensible of sounds produced at a distance outside such room; and they may be equally sensible of these, even though the windows and doors should be absolutely air-tight. In such case the undulations of the external air produce sympathetic vibration on the windows, doors or walls by which the hearers are enclosed, and then produce corresponding vibrations in the air within the room, by which the organs of hearing are immediately affected."

823. "*Propagation of sound progressive.*—Let a series of observers, *A. B. C.* &c., be placed in a line, at distances of about 1000 feet asunder, and let a pistol be discharged at *P.* about 1000 feet from the first observer.



This observer will see the flash of the pistol about one second before he hears the report. The observer *B.* will hear the report one second after it has been heard by *A.* and about two seconds after he sees the flash. In the same manner, the third observer at *C.* will hear the report one second after it has been heard by the observer at *B.* and two seconds after it has been heard by the observer at *A.* and three seconds after he perceives the flash. In the same way, the fourth observer at *D.* will hear the report one second later than it was heard by the third observer at *C.* and three seconds later than it was heard by the observer at *A.* and four seconds after he perceives the flash.

Now it must be observed, that at the moment the report is heard by the second observer at *B.* it has ceased to be audible to the first observer at *A.*, and when it is heard by the third observer at *C.* it has ceased to be heard by the second observer at *B.*, and so forth. It follows, therefore, from this, that sound passes through the air, not instantaneously, but progressively, and at a uniform rate."

824. "*Breadth of sonorous waves.*—As the sensation of sound is produced by the wave of air impinging on the membrane of the ear-drum exactly as the momentum of a wave of the sea would strike the shore, it follows that the interval between the production of sound and its sensation is the time which such a wave would take to pass through the air from the sounding body to the ear; and since these waves are propagated through the air in regular succession, one following another without overlaying each other, as in the case of waves upon a liquid, the breadth of a wave may always be determined if we take the number of vibrations which the sounding body makes in a second, and the velocity with which the sound passes through the air. If, for example, it be known that in a second a musical string makes 500 vibrations, and that the sound of this string takes a second to reach the ear of a person at a distance of 1000 feet, there are 500 waves in the distance of 1000 feet, and consequently each wave measures two feet.

The velocity of the sound, therefore, and the rate of vibration, are always sufficient data by which the length of the sonorous wave can be computed."

825. "*Distinction between musical sounds and ordinary sounds.*—It has not been ascertained, with any clearness or certainty, by what physical distinctions vibrations which produce common sounds or noises are distinguished from such as produce musical sounds. It is nevertheless certain, that all vibrations, in proportion as they are regular, uniform and equal, produce sounds proportionably more agreeable and musical.

Sounds are distinguished from each other by their pitch of tone, in virtue of which they are high or low by their intensity, of which they are loud or soft; and by a property expressed in French by the word *timbre* which we shall here adopt in the absence of any English equivalent."

826. "*Pitch of a sound.*—The pitch or tone of a sound is grave or acute. In the former case it is low, and in the latter high, in the musical scale. It will be shown hereafter that the physical condition which determines this property of sound is the rate of vibration of the sounding body. The more rapid the vibrations are, the more acute will be the sound. A bass note is produced by vibrations much less rapid than a note in the treble. But it will also be shown that the length of the sonorous wave depends on the rate of vibration of the body which produces it: the slower the rate of vibration, the longer will be the wave, and the more grave the tone. All the vibrations which are performed at the same rate produce waves of equal length and sounds of the same pitch."

827. "*Intensity or Loudness.*—The intensity of a sound or its degree of loudness, depends on the force with which the vibrations of the sounding body are made, and consequently upon the degree of condensation produced at the middle of the sonorous waves. Waves of equal length, but having different degrees of condensation at their centre, will produce notes of the same pitch, but of different degrees of loudness, in proportion to such degrees of condensation."

828. "*Timbre of a sound.*—The timbre of a sound is not easily explained; and still less easily can the physical conditions on which it depends be ascertained. If we hear the same musical note produced with the same degree of loudness in an adjacent room successively upon a flute, a clarionet, and a hautboy, we shall, without the least hesitation, distinguish the one instrument from the other. Now, this distinction is made by observing some peculiarity in the notes produced, yet the notes shall be the same, and be produced with equal loudness. This property by which the one sound is distinguished from the other, is called the timbre."

829. "*All sounds propagated with the same velocity.*—All sounds, whatever be their pitch, intensity, or timbre, are propagated through the same medium with the same velocity. That this is the case, is manifest from the absence of all confusion in the effects of music, at whatever distance it may be heard. If the different notes simultaneously produced by the various instruments of an orchestra moved with different velocity through the air, they would be heard by a distant auditor at different moments, the consequence of which would be, that a musical performance would, to the auditors, save those in immediate proximity with the performers, produce the most intolera-

ble confusion and cacophony; for, different notes produced simultaneously, and which, when heard together form harmony, would at a distance be heard in succession, and sounds produced in succession would be heard as if produced together, according to the different velocities with which each note would pass through the air."

830. "*Experiments on the velocity of sound.*—The velocity of sound varies with the elasticity of the medium by which it is propagated. Its velocity, therefore, through the air, will vary, more or less, with the barometer and thermometer.

The experimental methods which have been adopted to ascertain the velocity of sound are similar in principle to those which have been briefly noticed by way of illustration. The most extensive and accurate system of experiments which have been made with this object were those made at Paris by the Board of Longitude in the year 1822. The sounding bodies used on this occasion were pieces of artillery charged with from two to three pounds of powder, which were placed at Villejuif and Montlhéry. The experiments were made at midnight, in order that the flash might be more easily and accurately noticed. They were conducted by MM. Prony, Arago, Mathieu, Humboldt, Gay Lussac, and Bouvard. The result of the experiment was that, when the barometer was at 29.8 inches, and the thermometer at 61°, the velocity of sound was 1118.39 feet per second.

By calculation it is ascertained, that at the temperature of 50°, the velocity would be 1106.58 feet per second; and at 32°, the velocity would be 1086.37 feet per second.

Thus it appears that between 50° and 61°, the velocity of sound increases about 1.07 feet per second for every degree which the thermometer rises, and between 50° and 32°, it increases at the mean rate of 1.12 feet per second for each degree in the rise of the thermometer.

831. "*Method of estimating the distance of a sounding body by velocity of sound.*—The velocity of sound being known, the distance of a sounding body can always be computed by comparing the moment the sound is produced with the moment at which it is heard. The production of sound is in many cases attended with the evolution of light, as, for example, in fire-arms and explosions generally, and in the case of atmospheric electricity. In these cases, by noting the interval between the flash and the report, and multiplying the number of seconds in each interval by the number of feet per second in the velocity of sound, the distance can be ascertained with great precision.

Thus, if a flash of lightning be seen ten seconds before the thunder, which attends it, is heard, and the atmosphere be in such condition that the velocity of sound is 1120 feet per second, it is evident that the distance of the cloud in which the electricity is evolved must be 11,200 feet.

Among the numerous discoveries bequeathed to the world by Newton, was a calculation, by theory, of the velocity with which sound was propagated through the air. This calculation, based upon the elasticity and temperature of the air, gave as a result about one sixth less than that which resulted from experiments. This discrepancy remained without satisfactory explanation until it was solved by Laplace, who showed that it arose from the fact that Newton had neglected to take into account, in his computation, the effect of the heat developed and absorbed by the alternate compression and rarefaction of the air produced in the sonorous undulations. Laplace taking account of these, gave a formula for the velocity of sound which corresponds in its results equally with experiment."

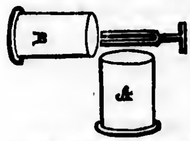
832. "*All gases and vapours conduct sound. Experimental illustrations.* As all elastic fluids are, in common with air, susceptible of undulation, they are equally capable of transmitting sound. This may be rendered experimentally evident by the following means. Let the alarum be placed under the receiver of an air pump, as already described, and let the receiver be exhausted. If, instead of introducing atmospheric air into the receiver we introduce any other elastic fluid, the sound of the alarum will become gradually audible, according to the quantity of such fluid which is introduced under the receiver. If a drop of any liquid which is easily evaporated be introduced, the atmosphere of vapour, which is thus produced, will also render the alarum audible."

833. "*The intensity of a sound increases with the density of the propagating medium.*—The same sounding body will produce a louder or lower sound, according as the density of the air which surrounds it is increased or diminished. In the experiment already explained, in which the alarum was placed under an exhausted receiver, the sound increased in loudness as more and more air was admitted into the receiver. If the alarum had been placed under a condenser, and highly compressed air collected round it, the sound would have been still further increased. When persons descend to any considerable depth in a diving-bell, the atmosphere around them is compressed by the

weight of the column of water above them. In such circumstances, a whisper is almost as loud as the common voice in the open air, and when one speaks with the ordinary force, it produces an effect so loud as to be painful.* On the summit of lofty mountains, where the barometric column falls to one half its usual elevation, and where, therefore, the air is highly rarefied, sounds are greatly diminished in intensity. Persons who ascend in balloons find it necessary to speak with much greater exertion, and as would be said louder, in order to render themselves audible, When Saussure ascended Mont Blanc, he found that the report of a pistol was not louder than a common cracker."†

837. "*Experimental illustration of interference of sound.*—This phenomena of interference may be produced in a striking manner by means of the common tuning-fork, used to regulate the pitch of musical instruments.

Let *A.* and *B.*, Fig. 243, be two cylindrical glass vessels, held at right angles to each other, and let the tuning-fork, after it has been put in vibration, be held in the middle of the angle formed by their mouths. Although, under such circumstances, the vibration of the tuning-fork will be imparted to the columns of air included within the two cylinders, no sound will be heard; but if either of the cylinders be removed the sound will be distinctly audible in the other. In this case the silence produced by the combined sounds is the consequence of inter-



* But, is this the effect as usually experienced? We have a recollection under such circumstances, of a sensation of oppression in the ears, and as of a continued peculiar noise, accompanied with a considerable difficulty in hearing any one speak.

† These instances are given as evidences in support of the proposition that the transmitting or propagating capability of the elastic fluid increases or decreases according to the increased or decreased density of the fluid. But they do not in themselves furnish any conclusive evidence, because the effects noticed may be, with equal probability, attributed to another cause. The necessity for greater exertion in the balloon may arise from a difficulty in speaking instead of a difficulty in hearing; and again, if the noise, in quantity of sound, be dependent on the concussion, the rarefaction of the air would diminish the violence of the concussion [occasioned by the explosion] in firing the pistol, and consequently less noise or quantity of sound would be produced.

ference. Another example of this phenomenon may be produced by the tuning-fork itself. If this instrument, after being put into vibration, be held at a great distance from the ear, and slowly turned round its axis, a position of the prongs will be found at which the sound will become inaudible. This position will correspond to the points of interference of the two systems of undulation propagated from the two prongs."

838. "*Examples of sounds propagated by solids.*—Solids which possess elasticity have likewise the power of propagating sound. If the end of a beam composed of any solid possessing elasticity be lightly scratched or rubbed, the sound will be distinct to an ear placed at the other end, although the same sound would not be audible to the ear of the person who produces it, and who is contiguous to the place of its origin. The earth itself conducts sound, so as to render it sensible to the ear when the air fails to do so. It is well known, that the approach of a troop of horses can be heard at a distance by putting the ear to the ground, In volcanic countries, it is said that the rumbling noise which is usually the prognostic of an eruption is first heard by the beasts of the field, because their ears are generally near the ground, and they then, by their agitation and alarm, give warning to the inhabitants of the approaching catastrophe. Savage tribes are well known to practise this method of ascertaining the approach of persons from a great distance.

The velocity with which sound is propagated through different media varies with their different physical conditions."

842. "*Biot's experiment on the relative velocities of sound in air and metal.*—The relative velocities of sound, as transmitted by air and metal, are illustrated by the following remarkable experiment of Biot:—A bell was suspended at the centre of the mouth of a metal tube 3000 feet long, and a ring of metal was at the same time placed close to the metal forming the mouth of the tube, so that when the ring was sounded its vibration might effect the metal of the tube, and when the bell was sounded its vibration might affect only the air included within the tube. A hammer was so adapted so as to strike the ring and the bell simultaneously. When this was done, an ear placed at the remote end of the tube heard the sound of the ring, and after a considerable interval heard the sound of the bell."*

* In the art. Acoustics of the Encyclopedia Britannica the length of the pipes is stated at 2550 feet. From a mean of two hundred trials the inter-

843. "*Chladni's experiment of hearing.*—The solids comprising the body of an animal are capable of transmitting the sonorous undulations to the organ of hearing, even though the air surrounding that organ be excluded from communicating with the origin of the sound. Chladni showed that two persons stopping their ears could converse with each other by holding the same stick between their teeth or by resting their teeth upon the same solid. The same effect was produced when the stick is pressed against the breast or the throat, and other parts of the body. If a person speaks, directing his mouth into a vessel composed of any vibratory substance, such as glass or porcelain, the other stopping his ears, and touching such vessel with a stick held between his teeth, he will hear the words spoken.

The same effect will take place with vessels composed of metal or wood. If two persons hold between their teeth the same thread, stopping their ears, they will hear each other speak, provided the thread be stretched tight."

The nature of sound.—

Sound, as already stated, is a form of force, of which the various manifestations on matter constitute the subjects of acoustic science.

The nature of sound, therefore, understanding by that term the influence which causes the acoustic effect, is spiritual.

In thus expressing the definition we do not mean that when a person hears a sound or combination of sounds the circumstance is correctly appreciated by supposing a mechanical result or effect is transmitted to the person's brain; on the contrary, we believe that, both in regard

val between the two sounds was found to be 2.79 seconds. The art. continues: "But the transmission of sound through the internal column of air would have taken 2.5 seconds; which leaves ·29" for the rapidity of the tremor conducted through the cast iron." It was concluded that the conduction (or transmission) through the iron occupied ten to twelve times less time than through the atmosphere.

to seeing and hearing, the spiritual influence is imparted to the spiritual being. The cognition by the human being of the influence must indeed take place through the medium of matter, but the *force* itself is the *light* or the *sound* and is wholly spiritual.

Nevertheless, there is abundant evidence that each of these forces can and does exert a potent influence on matter, and a distinction in the general character of the effects on matter caused respectively by each of them may be made:—Light acts molecularly (chemically) disturbing the internal molecular arrangement and in some cases causing combination or decomposition of the elements of the compounded matter. Sound acts volumetrically (mechanically) occasioning alteration in the arrangement, or dynamical disturbance in the relative positions, of the aggregated particles of which the matter consists.

The objection which we stated to the undulatory theory of light, *viz.*, that it has not been shown or explained how a number of undulations propagated through a material fluid (the ether) in various directions can cross each other at angles of all degrees of obliquity and yet not destroy, interfere with or modify each other, applies also to the aereal waves or vibratory pulses which are supposed to propagate the effect called sound.

We are decidedly of opinion that this objection alone in its application to the aereal wave theory of sound is quite insurmountable and fatal. Other facts opposed to the theory and irreconcilable with it, have been, in our quotations from the record, abundantly put before the reader: for example, (1) the conduction or transmission of sound through water and through metallic and other solid bodies with considerably greater velocity than through air. In the undulatory theory of light the hypothetical ether is supposed to occupy the interstices between the constituent particles of metals and other solids: but in the kindred theory of the aereal sound undulations, not even hypothesis can venture to suppose the interstices between the particles of metals and other solids, occupied by air. (2) The much greater velocity with which sound is transmitted by the medium of these solids. (3) Chladni's experiment of two persons conversing by means of a stick held between the teeth, having their ears stopped. (4) The familiar fact that sound is transmitted through air in one direction whilst the air itself is in rapid motion in the opposite direction. (5) The fact that a feeble and a very loud sound are transmitted with equal velocities.

We are not disputing or questioning the established facts of acoustics. That the mode of the communication in which the acoustic force is transmitted from the place where the active force is disengaged to the recipient, is such as may be termed an undulation or vibratory pulse, and that the note or quality of the sound is dependent upon the greater or lesser rapidity, and upon the regularity or irregularity of the vibrations, is, we opine, established as a general fact belonging to the subject. Many of the subordinate regulations or laws, under which the manifestations of this force upon matter operate, have been successfully investigated.

It is not, however, the purpose of this work to enter at length into the particular facts and phenomena belonging to such a department of science as acoustics and optics further than is necessary to support and establish the opinions we have advanced on the fundamental doctrines pertaining to the subjects of sound and light. The record of most of the interesting and important investigations which have been made in this department is contained in the comprehensive and very useful treatise of Dr. Lardner from which we have so largely quoted. Students of science wishing to become acquainted with the most recent physical observations and discoveries relating to acoustics illustrated by refined exposition and experiment may avail themselves of the instruction afforded by Prof. Tyndall's Eight Lectures on Sound.

MAGNETIC AND THERMAL EFFECTS OF ELECTRICITY.

Fowne's Manual of Chemistry. Part I. Physics, page 72.

"Not long before two very remarkable facts had been discovered. Oersted, in Copenhagen, showed that a current of electricity, however produced, exercises a singular and perfectly definite action on a magnetic needle; and Seebeck, in Berlin, found that an electric current may be generated by the unequal effects of heat on different metals in contact. If a wire conveying an electrical current be brought near a magnetic needle, the latter will immediately alter its position and assume a new one, as nearly perpendicular to the wire as the mode of suspension and the magnetism of the earth will permit. When the wire, for example, is placed directly over the needle, while the current it carries travels from north to south, the needle is deflected from its ordinary direction and the north pole driven to the eastward. When the current is reversed, the same pole deviates to an equal amount towards the west. Placing the wire below the needle instead of above produces the same effect as reversing the current.

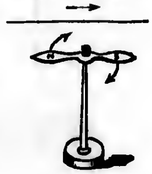


Fig. 52.

When the needle is subjected to the action of two currents in opposite directions, the one above and the other below, they will obviously concur in their effects. The same thing happens when the wire carrying the current is bent upon itself, and the needle placed between the two portions; and since every time the bending is repeated a fresh portion of the current is made to act in the same manner upon the needle, it is easy to see how a current, too feeble to produce any effect when a single straight wire is employed, may be made by this contrivance to exhibit a powerful action on the magnet. It is on this principle that instruments called *galvanometers*, *galvanoscopes*,

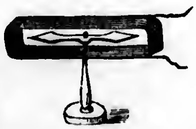


Fig. 53.

or *multipliers* are constructed; they serve, not only to indicate the existence of electrical currents, but to show by the effect upon the needle the direction in which they are moving. By using a very long coil of wire, and two needles, immovably connected, and hung by a fine filament of silk, almost any degree of sensibility may be communicated to the apparatus.*

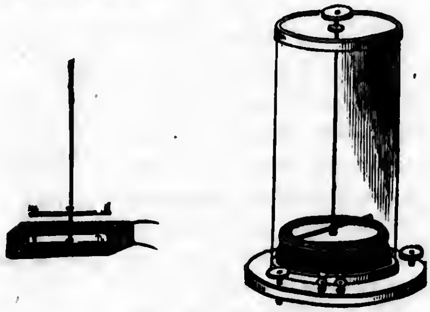


Fig. 69.

When two pieces of different metals connected together at each end, have one of their points more heated than the other, an electric current is immediately set up. Of all the metals tried, bismuth and antimony form the most powerful combination. A single pair of bars, having one of their junctions heated in the manner shown, can develope a current strong enough to

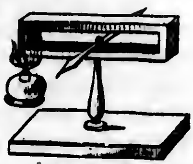


Fig. 54 (a).

* The common galvanoscope, consisting of a coil of wire having a compass-needle suspended on a point within it, is greatly improved by the addition of a second needle, as already in part described, and by a better mode of suspension, a long fibre of silk being used for the purpose. The two needles are of equal size, and magnetized as nearly as possible to the same extent; they are then immovably fixed together, parallel, and with their poles opposed and hung with the lower needle in the coil and the upper one above it. The advantage gained is two-fold: the system is *astatic*, unaffected, or nearly so, by the magnetism of the earth; and the needles being both acted upon in the same manner by the current, are urged with much greater force than one alone would be, all the actions of every part of the coil being strictly concurrent. A divided circle is placed below the upper

deflect a compass-needle placed within, and, by arranging a number in a series and heating their alternate ends, the intensity of the cur-

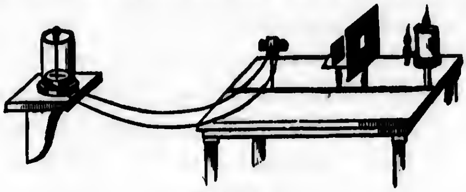


Fig. 54.

rent may be very much increased. Such an arrangement is called a thermo-electric pile. M. Melloni constructed a very small thermo-electric pile of this kind, containing fifty-five slender bars of bismuth and antimony, laid side by side and soldered together at their alternate ends. He connected this pile with an exceedingly delicate multiplier, and found himself in the possession of an instrument for measuring small variations of temperature far surpassing in delicacy the air-thermometer in its most sensitive form, and having great advantages in other respects over that instrument when employed for the purposes to which he devoted it." (See Fig. 54).

By means of this apparatus, the close analogy between radiant heat and light was made apparent. The example here given illustrates the conversion of heat (caloric force) into molecular-electricity (voltaic electric force).

Examples of the connection between Volumetric (frictional), and Molecular (voltaic) Electricity are . . .The production of Magnetism. .of Chemical decomposition. . of Light. .and of Heat,(*e. g.* in the heating and fusion of a conducting wire) . . . . effects which result from the action of both (*i.e.*, of either one of) those forces, or forms of force, on compound matter. And the relation of 'motion' and 'mechanical-effect' to each of those forces is shown in the production of volumetric electricity

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needle, by which the regular motion can be measured; and the whole is enclosed in glass, to shield the needles from the agitation of the air. The whole is shown in Fig. 69.

by friction in the plate or cylinder electrical machine; and in the production of molecular electricity by the rotation of an armature (a piece of iron) in front of the poles of a magnet. The production of volumetric electricity by a jet of steam also shows the connection of that force with mechanical-effect, and also with heat (because the mechanical effect of the steam results from the addition of caloric force to the water.) And, again, in the development of the same kind of electricity (volumetric) by or in certain animals (fishes)—*e. g.*, the Gymnotus, electricity is seen to be closely connected with nervous power, (*i. e.*, with mechanical-effect)...the electric shock is given at the will of the animal, and great exhaustion follows the repeated exertion of the power.

The proposition that compound matter is compounded of force together with matter, and that the distinctive characteristics of the compound substance are dependent upon the definite proportional quantity of force which enters into its composition and constitutes a part of it, may be demonstrated by the facts belonging to chemical and physical science.

Lardner's Natural Philosophy.

(1799) "*A Current of Electricity passing over a Conductor raises its Temperature.*—If a current of electricity pass over a conductor as would happen when the conductor of an electrical machine is connected by a metallic rod with the earth, no change in the thermal condition of the conductor will be observed so long as its transverse section is so considerable as to leave sufficient space for the free passage of the fluid. But if its thickness be diminished, or the quantity of fluid passing over it be augmented, or, in general, if the ratio of the fluid to the magnitude of the space afforded to it be increased, the conductor will be found to undergo an elevation of temperature, which will be greater the greater the quantity of the electricity and the less the space supplied for its passage."

(1800.) "*Experimental Verification, Wire heated, fused, and burned.*—If a piece of wire of several inches in length be placed upon the stage of the universal discharger, a feeble charge transmitted through it will sensibly raise its temperature. By increasing the strength of the charge, its temperature may be elevated to higher and higher points of the thermometric scale; it may be rendered incandescent, fused, vaporized, and, in fine, burned.

With the powerful machine of the Taylerian Museum at Haarlem, Van Marum fused pieces of wire, above 70 feet in length.

Wire may be fused in water; but the length which can be melted in this way is always less than in air, because the liquid robs the metal of its heat more rapidly than air.

A narrow ribbon of tinfoil, from 4 to 6 inches in length, may be volatilized by the discharge of a common battery. The metallic vapor is, in this case, oxidized in the air, and its filaments float like those of a cobweb."

(1801.) "*Thermal effects are greater as the Conducting Power is less.*—These thermal effects are manifested in different degrees in different metals, according to their varying powers. The worse conductors of electricity, such as platinum and iron, suffer much greater changes of temperature by the same charge than the best conductors, such as gold and copper. The charge of electricity, which only elevates the temperature of one conductor, will sometimes render another incandescent, and will volatilize a third."

(1802.) "*Ignition of Metals.*—If a fine silver wire be extended between the rods of the universal discharger, a strong charge will make it burn with a greenish flame. It will pass off in a greyish smoke; other metals may be similarly ignited, each producing a flame of a peculiar colour. If the experiments be made in a receiver, the products of the combustion being collected, will prove to be the metallic oxides.

If a gilt thread of silk be extended between the rods of the discharger, the electricity will volatilize or burn the gilding, without affecting the silk. The effect is too rapid to allow the time necessary for the heat to affect the silk.

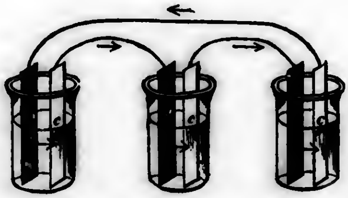
A strip of gold or silver leaf placed between the leaves of paper, being extended between the rods of the discharger, will be burnt by a discharge from a jar having two square feet of coating. The metallic oxide will in this case appear on the paper as a patch of purple colour in the case of gold, and of grey colour in that of silver.

A spark from the prime conductor of the great Haarlem machine burnt a strip of gold leaf twenty inches long by an inch and a half broad."

(1806.) "*Resinous Powder Burned.*—The electric charge transmitted through fine resinous powder, such as that of Colophony, will ignite it. This experiment may be performed either by spreading the powder on the stage of the discharger, or by impregnating a hank of cotton with it; or, in a still more striking manner, by sprinkling it on the surface of water contained in an eathenware saucer."

MOLECULAR (VOLTAIC) ELECTRICITY AND MATTER.

Fowne's Chemistry, Page 92.—The second form of apparatus, or crown of cups, is precisely the same in principle, although different in appearance. A number of cups or glasses are arranged in a row or circle, each containing a piece of active and a piece of inactive metal and a portion of exciting liquid; zinc, copper, and dilute sulphuric acid, for example. The copper of the first cup is connected with the zinc of the second, the copper of the second with the zinc of the third, and so to the end of the series. On establishing a communication between the first and last plates by means of a wire, or otherwise, discharge takes place in the form of a bright enduring spark or stream of fire.



(Page 206). "When a voltaic current of considerable power is made to traverse various compound liquids, a separation of the elements of these liquids ensues; provided that the liquid be capable of conducting a current of a certain degree of energy, its decomposition almost directly follows.

The elements are disengaged solely at the limiting surface of the liquid; where, according to the common mode of speech, the current enters and leaves the latter, all the intermediate portions appearing perfectly quiescent. In addition, the elements are not separated indifferently and at random at these two surfaces, but, on the contrary, make their appearance with perfect uniformity and constancy at one or the other, according to their chemical character, namely—oxygen, chlorine, iodine, acids, etc., at the surface connected with the *copper* or *positive* end of the battery; hydrogen, the metals, etc., at the surface in connection with the *zinc* or *negative* extremity of the arrangement.*

The terminations of the battery itself, usually, but by no means necessarily of metal, are designated poles or *electrodes*, as by their intervention the liquid to be experimented on is made a part of the circuit. The process of decomposition by the current is called *electrolysis*, and the liquids, which, when thus treated, yield up their elements, are denominated *electrolytes*.

When a pair of platinum plates are plunged into a glass of water to which a few drops of oil of vitriol have been added, and the plates connected by wires with the extremities of an active battery, oxygen is disengaged at the positive electrode, and hydrogen at the negative, in the proportion of one measure of the former to two of the latter nearly.

A solution of hydrochloric acid mixed with a little Saxon blue (indigo), and treated in the same manner, yields hydrogen on the negative side, and chlorine on the positive, the indigo there becoming bleached.

Iodide of potassium dissolved in water is decomposed in a similar manner, and with still greater ease; the free iodine at the positive side can be recognized by its brown colour, or by the addition of a little gelatinous starch.

*Note the evidence here that compounded matter as usually cognized by us, is compounded of force and matter; and that the active force may be transmitted (communicated) through the combined (latent) force without either mechanical or molecular disturbance of the material elements. This evidence may be compared with that in Optics and Acoustics, where the communication or transmission of the force through air (or through other fluid or solid) is unattended with displacement of the material particles.

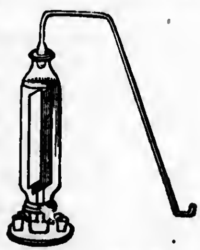
Every liquid is not an electrolyte; many refuse to conduct, and no decomposition can then occur; alcohol, ether, numerous essential oils, and other products of organic chemistry, besides a few saline inorganic compounds, act in this manner, and completely arrest the current of a very powerful battery. It is a very curious fact, and well deserves attention, that very nearly, if not all the substances acknowledged to be susceptible of electrolytic decomposition, belong to one class; they are all binary compounds, containing single equivalents of their components, the latter being strongly opposed to each other in their chemical relations, and held together by very powerful affinities."

"The metallic terminations of the battery, the poles or electrodes, have, in themselves, nothing in the shape of attractive or repulsive power for the elements so often separated at their surfaces. Finely-divided metal suspended in water, or chlorine held in solution in that liquid, shows not the least symptom of a tendency to accumulate around them; a single element is altogether unaffected, directly at least; severance from previous combination is required, in order that this appearance should be exhibited.

It is necessary to examine the processes of electrolysis a little more closely. When a portion of water, for example, is subjected to decomposition in a glass vessel with parallel sides, oxygen is disengaged at the positive electrode, and hydrogen at the negative; the gases are pure and unmixed. If, while the decomposition is proceeding, the intervening water be examined by a beam of light, or by other means, not the slightest disturbance or movement of any kind will be perceived, nothing like currents in the liquid or bodily transfer of gas from one part to another can be detected, and yet two portions of water, separated perhaps by an interval of four or five inches, may be respectively evolving pure oxygen and hydrogen."

"If a number of different electrolytes, such as acidulated water, sulphate of copper, iodide of potassium, fused chloride of lead, &c., be arranged in a series, and the same current be made to traverse the whole, all will suffer decomposition at the same time, but by no means to the same amount. If arrangements be made by which the quantity of the eliminated elements can be accurately ascertained, it will be found, when the decomposition has proceeded to some extent, that these latter will have been disengaged exactly in the *ratio of the chemical equivalents*. The same current which decomposes 9 parts of water will separate into their elements 166 parts of iodide of potassium, 139·2 parts of chloride of lead, &c. Hence the very important conclusion: The action of the current is perfectly definite in its nature, producing a fixed and constant amount of decomposition, expressed in each electrolyte by the value of its chemical equivalent."

From a very extended series of experiments, based on this and other methods of research, Mr. Faraday was enabled to draw the general inference that effects of chemical decomposition were always proportionate to the quantity of circulating electricity, and might be taken as an accurate and trustworthy measure of the latter. Guided by this highly important principle he constructed his *voltameter*, an instrument which has rendered the greatest service to electrical science. This is merely an arrangement by which a little acidulated water is decomposed by the current, the gas evolved being collected and measured. By placing such an instrument in any part of the circuit, the quantity of electric force necessary to produce any given effect can be at once estimated; or, on the other hand,



any required amount of the latter can be, as it were, measured out and adjusted to the object in view. The voltameter has received many different forms; one of the most extensively useful is that figured, in which the platinum plates are separated by a very small interval, and the gas is collected in a graduated jar standing on the shelf of the pneumetic trough, the tube of the instrument, which is filled to the neck with dilute sulphuric acid, being passed beneath the jar."

"The experiments of Mr. Faraday and Professor Daniell have given very great support to the chemical theory, by shewing that contact of dissimilar metals is not necessary in order to call into being powerful electrical currents, and that the development of electrical force is not only in some way connected with the chemical action of the liquid of the battery, but that it is always in direct proportion to the latter. One very beautiful experiment, in which the decomposition of iodide of potassium by real electrolysis is performed by a current generated without any contact of dissimilar metals can be thus made:—A plate of zinc is bent at a right angle, and cleaned by

rubbing with sand-paper. A platinum plate has a wire of the same metal attached to it by carefully rivetting, and the latter bent into an arch. A piece of folded filter-paper is wetted with solution of iodide of potassium, and placed upon the zinc; the platinum plate is arranged opposite to the latter, with the end of its wire resting upon the paper, and then the pair plunged into a glass of dilute sulphuric acid, mixed with a few drops of nitric. A brown spot of iodine becomes in a moment evident beneath the extremity of the platinum wire; that is, at the positive side of the arrangement.

A strong argument in favour of the chemical view is founded on the easily proved fact, that the direction of the current is determined by the kind of action upon the metals, the one least attacked being always positive. Let two polished plates, the one iron and the other copper, be connected by wires with a galvanometer, and then immersed in a solution of an alkaline sulphide. The needle in a moment indicates a powerful current, passing from the copper, through the liquid, to the iron, and back again through the wire. Let the plates be now removed, cleaned, and plunged into dilute acid; the needle is again driven round, but in the opposite direction, the current now passing from the iron, through the liquid, to the copper. In the first instance the copper is acted upon, and not the iron; in the second, these conditions are reversed, and with them the direction of the current."

"The principle of the compound battery is, perhaps, best seen in the crown of cups*; by each alternation of zinc, fluid, and copper, the current is urged forward with increased energy, its intensity is augmented, but the actual amount of electrical force thrown into the current form† is not increased. The quantity estimated by its decomposing power is in fact determined by that of the smallest and least active pair of plates, the quantity of electricity in every part or section of the circuit being exactly equal. Hence large and small plates, batteries strongly and weakly charged, can never be connected without great loss of power."

"When a battery, either simple or compound, constructed with pure or amalgamated zinc, is charged with diluted sulphuric acid, a

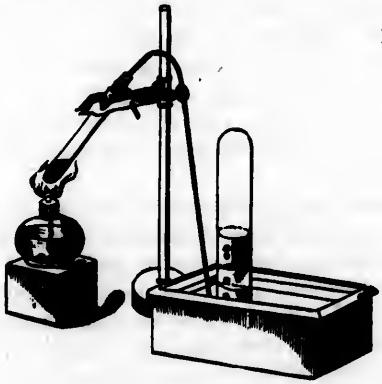
* See page 153.

† *i.e.*, The quantity of force rendered dynamic.

number of highly interesting phenomena may be observed. While the circuit remains broken the zinc is perfectly inactive, no water is decomposed, no hydrogen liberated; but the moment the connection is completed, torrents of hydrogen arise, not from the zinc, but from the copper or platinum surfaces alone, while the zinc undergoes tranquil and imperceptible oxidation and solution. Thus, exactly the same effects are seen to occur in every active cell of a closed circuit which are witnessed in a portion of water undergoing electrolysis; the oxygen appears at the positive side, with respect to the current, and the hydrogen at the negative; but with this difference, that the oxygen instead of being set free combines with the zinc.* It is, in fact, a real case of electrolysis, and electrolytes alone are available as exciting liquids."

"From experiments very carefully made with a dissected battery of peculiar construction, in which local action was completely avoided, it has been distinctly proved that the quantity of electricity set in motion by the battery varies with the zinc dissolved. Coupling this fact with that of the definite action of the current, it will be seen that

Fig. 73.



MOLECULAR FORCE AND THE MATERIAL ELEMENTS OF COMPOUND MATTER.

* It may be therefore considered— a combustion of the zinc in which a definite quantity of molecular force is set free in the form of molecular (voltaic) electricity, instead of in the form of heat (caloric force) as in ordinary combustion—which last may be termed, for the sake of distinction, gaseous oxidation, the former being termed nascent or liquid oxidation.

when a perfect battery of this kind is employed to decompose water, in order to evolve 1 grain of hydrogen from the latter, 33 grains of zinc must be oxidised and its equivalent quantity of hydrogen disengaged in each active cell of the battery. That is to say, that the electrical force generated by the oxidation of an equivalent of zinc in the battery, is capable of affecting the decomposition of an equivalent of water, or any other electrolyte out of it."

"The red oxide of mercury is placed in a short tube of hard glass, to which is fitted a perforated cork, furnished with a piece of narrow glass tube, bent as in the figure. The heat of a spirit lamp being applied to the substance, decomposition speedily commences, globules of metallic mercury collect in the cool part of the wide tube, which answers the purpose of a retort, while gas issues in considerable quantity from the apparatus. This gas is collected and examined by the aid of the pneumatic trough, which consists of a vessel of water provided with a shelf, upon which stands the jars or bottles destined to receive the gas, filled with water and inverted.

By keeping the level of the liquid above the mouth of the jar, the water is retained in the latter by the pressure of the atmosphere, and entrance of air is prevented. When brought over the extremity of the gas-delivery tube, the bubbles of gas rising through the water collect in the upper part of the jar and displace the liquid. As soon as one jar is filled, it may be removed, still keeping its mouth below the water level and another substituted. The whole arrangement is shown in Fig. 73.

The experiment described is more instructive as an excellent case of the resolution by simple means of a compound body into its constituents, than valuable as a source of oxygen gas. A better and more economical method is to expose to heat in a retort, or flask furnished with a bent tube, a portion of the salt called chlorate of potassa. A common Florence flask answers perfectly well, the heat of a spirit lamp being sufficient. The salt melts and decomposes with ebullition, yielding a very large quantity of oxygen gas, which may be collected in the way above described. The first portion of the gas often contains a little chlorine. The white saline residue in the flask is chloride of potassium."

These facts serve to show the intimate nature of the connection between chemical and electrical forces,—*i.e.*, between those forms of force.

We have adopted the term 'caloric-force' as including the two distinct forms or modes of heat known as *radiant* (or *free*) and *latent* (or *combined*) heat. Of these, *radiant* heat may be considered as nearly allied to volumetric electricity and to light; whilst *latent* heat appears to be more closely allied in its characteristics to molecular electricity, for it enters into and modifies or changes the internal physical condition of the compound matter.

The inter-relation of these two forms of force, namely radiant and latent heat, has to be now briefly considered.

Note.—It may be observed that the phenomena of latent heat (and of specific heat) together with those of isomorphism, strongly support the proposition that compound matter consists of elementary matter compounded with force.

Fowne's Chemistry.—Heat...Change of state.

"If equal weights of water at 32°, and water at 174°, be mixed, the temperature of the mixture will be the mean of the two temperatures, or 103°. If the same experiment be repeated with snow, or finely powdered ice, at 32° and water at 174° the temperature of the whole will be still only 32°, *but the ice will have been melted.*

$$\left.\begin{array}{l}1\ \text{lb. of water at }\ 32^\circ.\\ 1\ \text{lb. of water at }174^\circ.\end{array}\right\} = 2\ \text{lbs. water at }103^\circ.$$

$$\left.\begin{array}{l}1\ \text{lb. of ice at }\ 32^\circ.\\ 1\ \text{lb. of water at }174^\circ.\end{array}\right\} = 2\ \text{lbs. water at }32^\circ.$$

In the last experiment, therefore, as much heat has been apparently lost as would have raised a quantity of water equal to that of the ice through a range of 142°. The heat thus become insensible to the thermometer in effecting the liquefaction of the ice, is called latent heat, or better, heat of fluidity.

Again, let a perfectly uniform source of heat be imagined, of such intensity that a pound of water placed over it would have its temperature raised 10° per minute. Starting with water at 32°, in rather more than fourteen minutes its temperature would have risen 142°; but the same quantity of ice at 32°, exposed for the same interval of time would not have its temperature raised a single degree. But, then, it would have become water; the heat received would have been exclusively employed in effecting a change of state.

The heat is not lost, for when the water freezes it is again evolved. If a tall jar of water, covered to exclude dust, be placed in a situation where it shall be quite undisturbed, and at the same time exposed to great cold, the temperature of the water may be reduced 10° or more below its freezing-point without the formation of ice; but then if a little agitation be communicated to the jar, or a grain of sand dropped into the water, a portion instantly solidifies, and the temperature of the whole rises to 32°; the heat disengaged by the freezing of a small portion of the water will have been sufficient to raise the whole contents of the jar 10°." "The law thus illustrated in the case of water is perfectly general. Whenever a solid becomes a liquid, a certain fixed and definite amount of heat disappears or becomes latent; and conversely, whenever a liquid becomes a solid, heat to a corresponding extent is given out. The amount of latent heat varies much with different substances, as will be seen by the table:—

Water	142°	Zinc	193°
Sulphur	145°	Tin	500°
Lead	162°	Bismuth	500°

A law of exactly the same kind as that described affects universally the gaseous condition; change of state from solid or liquid to gas is accompanied by absorption of sensible heat, and the reverse by its disengagement. The latent heat of steam and other vapours may be ascertained by a similar mode of investigation to that employed in the case of water.

When water at 32° is mixed with an equal weight of water at 212° the whole is found to possess the mean of the two temperatures, or 122°; on the other hand, 1 part by weight of steam at 212° when condensed into cold water, is found to be capable of raising 5·6 parts of the latter from the freezing to the boiling point, or through a range of 180°. Now 180+5·6=1008; that is to say, steam at 212° in becoming water at 212°, parts with enough heat to raise a weight of water equal to its own (if it were possible) 1008° of the thermometer. When water passes into steam, the same quantity of sensible heat becomes latent."

"It is a very remarkable fact, that the latent heat of steam diminishes as the temperature of steam rises, so that equal weights of steam thrown into cold water exhibit nearly the same heating power, although the actual temperature of the one portion may be 212° and that of the other 350°. This also appears true with temperatures below the boiling point: so that it seems to evaporate a given quantity of water the same absolute amount of heat is required, whether it be performed slowly at the temperature of the air, in a manner presently to be noticed, or whether it be boiled off under the pressure of twenty atmospheres."

Capacity for Heat; Specific Heat.

"Let the reader renew a supposition made when the doctrine of latent heat was under consideration; let him imagine the existence of an uniform source of heat, and its intensity such as to raise a given weight of water 10° in 30 minutes. If, now, the experiment be repeated with equal weights of mercury and oil, it will be found, that instead of 30 minutes, 1 minute will suffice in the former case, and 15 minutes in the latter. This experiment serves to point out the very important fact, that different bodies have different *capacities for heat;* that equal weights of water, oil, and mercury, require, in order to rise through the same range of temperature,—quantities of heat in the proportion of the numbers 30, 15, and 1. This is often expressed by saying that the *specific heat* of water is 30 times as great as that of mercury, and the specific heat of oil 15 times as great."

"MM. Dulong and Petit observed in the course of their investigation a most remarkable circumstance. If the specific heats of bodies be computed upon equal weights, numbers are obtained, all different, and exhibiting no simple relations among themselves; but if, instead of equal weights, quantities be taken in the proportion of the chemical equivalents, an almost perfect coincidence in the numbers will be observed, shewing that some exceedingly intimate connection must exist between the relations of bodies to heat and their chemical nature."

CALORIC FORCE AND MECHANICAL EFFECT.

The following, taken also from *Fownes' Manual of Chemistry*, are instances of the correlation (inter-relation) of caloric-force and mechanical effect.

"An experiment of Court Rumford is on record, in which the heat developed by the boring of a brass cannon was sufficient to bring to the boiling point two and a half gallons of water, while the dust or shavings of metal, cut by the boror, weighed a few ounces only."

"Sir H. Davy melted two pieces of ice by rubbing them together in vacuo at 32°; and uncivilized men, in various parts of the world, have long been known to obtain fire by rubbing together two pieces of dry wood."

"A soft iron nail may be made red hot by a few dexterous blows on an anvil; but the experiment cannot be repeated until the metal has been *annealed*, and in that manner restored to its original physical state."

To these examples may be added, that of the heat given out by air and other gas when subjected to mechanical pressure,* and that of the steam-engine, in which a portion of the heat imparted to the water may be considered to be converted into mechanical effect. †

Magnetism.—The phenomena belonging to what is termed magnetism are to be considered as included under the more general title molecular electricity. They are, however, advantageously studied as a separate class or subdivision.

For the purpose of distinguishing this division of the one form of force into two kinds of manifestation, the

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*The 'caloric-engine' (of Ericson) in which the expansion of air by heat furnishes the motive power, may be mentioned as another illustration.

† A little consideration will make apparent that a distinction should be made between the case of a high-pressure, and of a condensing engine; in the former the sensible (radiant) heat, which is contained in the steam, above the temperature of 212° and occasions the pressure in excess of atmospheric pressure, may be considered as directly converted into mechanical effect; in the latter (the condensing engine) the latent heat contained in the steam through condensation of the steam and production of the vacuum, is, so to speak, indirectly converted into and utilized as mechanical effect.

term 'magnetism' might be amplified into magnetic electricity, and molecular electricity be considered to comprise { Voltaic or Chemical electricity, Magnetic electricity.

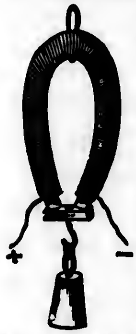
The one class of phenomena belongs to the investigation of the influence of molecular electricity upon the elementary constituents of which compound matter is compounded, and the circumstances under which that influence causes those elements to combine or to separate. The other class—that of magnetic electricity—belongs to the investigation of the physical influence of electricity on the various descriptions of compounded matter. That magnetism is a manifestation of molecular (voltaic) electricity, is shown by the following:—

Fownes' Manual of Chemistry.

Page 96. "A little consideration will show that, from the peculiar nature of the electro-dynamic force, a wire carrying a current, bent into a spiral or helix, must possess the properties of an ordinary magnetized bar, its extremities being attracted and repelled by the poles of a magnet. Such is really found to be the case, as may be proved by a variety of arrangements, among which it will be sufficient to cite the beautiful little apparatus of Professor De la Rive: A short wide glass tube is fixed into a cork ring of considerable size; a little voltaic battery, consisting of a single pair of copper and zinc plates, is fitted to the tube, and to these the ends of the spiral are soldered. On filling the tube with dilute acid and floating the whole

in a large basin of water, the helix will be observed to arrange itself in the magnetic meridian, and on trial it will be found to obey a magnet held near it in the most perfect manner as long as the current circulates."

"When an electric current is passed at right angles to a piece of iron or steel, the latter acquires magnetic polarity; either temporary



or permanent, as the case may be, the direction of the current determining the position of the poles. This effect is prodigiously increased by causing the current to circulate a number of times round the bar, which then acquires extraordinary magnetic power. A piece of soft iron, worked into the form of a horse-shoe, and surrounded by a coil of copper wire covered with silk or cotton for the purpose of insulation, furnishes an excellent illustration of the inductive energy in this respect; when the ends of the wire are put into communication with a small voltaic battery of a single pair of plates, the iron instantly becomes so highly magnetic as to be capable of sustaining a very heavy weight.

A current of electricity can thus develop magnetism in a transverse direction to its own; in the same manner magnetism can call into activity electric currents. If the two extremities of the coil of the electro-magnet above described be connected with a galvanoscope, and the iron magnetized by the application of a permament steel horse-shoe magnet to the ends of the bar, a momentary current will be developed in the wire, and pointed out by the movement

Fig. 72.

of the needle. It lasts but a single instant, the needle returning after a few oscillations to a state of rest. On removing the magnet, whereby the polarity of the iron is at once destroyed, a second current or wave will become apparent, but in the opposite direction to that of the first.

By employing a very powerful steel magnet, surrounding its iron keeper or armature with a very long coil of wire, and then making the armature itself rotate in front of the faces of the magnet, so that its polarity shall be rapidly reversed, magneto-electric currents may be produced, of such intensity as to give bright sparks and most powerful shocks, and exhibit all the phenomena of voltaic electricity. Fig. 72 represents a very powerful arrangement of this kind."

"When two covered wires are twisted together or laid side by side for some distance, and a current transmitted through the one, a momentary electrical wave will be induced in the reverse direction, and on breaking connexion with the battery, a second single wave will become evident by the aid of the galvanoscope, in the same direction as that of the primary current."

Lardner's Natural Philosophy.—Magnetism by induction.

(1630.) "*Soft iron rendered temporarily magnetic.*—If the poles of a magnet, this bar will itself become immediately magnetic. It will manifest a neutral line and two poles, that pole which is in contact with the magnet being of a contrary name to the pole which it touches. Thus if *A. B.*, Fig. 462, be the bar of soft iron which is brought in contact with the boreal pole *b.* of the magnet *a.b.*, then *A.* will be the austral and *B.* the boreal pole* of the bar of soft iron thus rendered

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* The term austral is applied (by Lardner, 1656) to the pole of the magnet which points towards the north pole of the earth, and boreal to the opposite pole of the magnet which points to the south. The expressions so applied are somewhat likely to cause misunderstanding. In the case of volumetric electricity, we do not think the theory of two distinct forces or forms of force is, in the present state of scientific knowledge, unreasonable although we are strongly of opinion that the facts will be found eventually not to support that theory. In applying the same theory or a modification of it to the case of magnetism there would not be, we opine, the same reasonableness. The fact that a coil of wire which is conducting voltaic electricity displays the properties of a magnet (as in De La Rive's apparatus, described by Fownes) and the fact, stated (Art. 1634) by Lard-

magnetic by contact, and *E.* will be its equator, which, however, will not be the middle of the bar, but nearer to the point of contact."

Fig. 462.

"The state of the bar *A. B.* can be rendered experimentally manifest by any of the tests already explained. If it be rolled in iron filings, they will attach themselves in two tufts separated by an intermediate point which is free from them; and if the test pendulum * be successively presented to different points of the bar, the varying intensity of the attraction will be indicated."

"If the bar *A. B.* be detached from the magnet, it will instantly lose its magnetic virtue.

(1631.) "It is not necessary, to produce these effects, that the bar of soft iron should be brought into actual contact with the pole of a magnet. It will be manifested, only in a less degree, if it be brought into proximity with the pole without contact. If the bar *A. B.* be presented at a small distance from the pole *b.*, it will manifest magnetism in the same manner; and if it be gradually removed from the pole, the magnetism it manifests will diminish in degree, until at length it wholly disappears."

(1634.) "It might be supposed, from what has been stated, that if a magnetic bar were divided at its equator, two magnets would be produced, one having austral and the other boreal magnetism, so that one of them would attract an austral and repel a boreal pole, while the other would produce the contrary attraction and repulsion. This, however, is not found to be the case. If a magnet be broken in two by its equator, two complete magnets will result, having each an equator at or near the centre, and two poles, austral and boreal; and if these be again broken, other magnets will be formed, each having

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ner himself, that if a magnet be divided each of the parts is a complete magnet in itself (*i.e.*, having an equator and two poles), taken together controvert such a supposition.

* A small ball of iron suspended by a fibre of silk. The ball is attracted or repelled out of the perpendicular when brought near to the respective poles of the magnet.

an equator and two poles as before; and in the same manner, whatever be the number of parts, and however minute they be, into which a magnet is divided, each part will still be a complete magnet with an equator and two poles."*

Fig. 26.

(1638.) "*Effect of induction on hard iron or steel.*—If a bar of hard iron or steel be placed with its end in contact with a magnet in the same manner as has been already described with respect to soft iron, it will exhibit no magnetism; but if it be kept in contact with the magnet for a considerable length of time, it will gradually acquire the same magnetic properties as have been described in respect to bars of soft iron, with this difference, however, that having thus acquired them, it does not lose them when detached from the magnet, as is the case with soft iron. Thus it would appear, that it is not literally true that a bar of steel when brought into contact with the pole of a magnet receives no magnetism, but rather that it receives magnetism in an insensible degree; for if continued contact impart sensible magnetism, it must be admitted that contact for shorter intervals must impart more or less magnetism, since it is the accumulation of the effects produced from moment to moment that the sensible magnetism manifested by continued contact is produced."

(1642.) "A red heat destroys the magnetism of iron. If a magnet, no matter how powerful, natural or artificial, be raised to a red heat,

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* We would suggest for consideration, whether sufficient prominence has been generally given to the full significance of this fact. The statement is definite and distinct, and when fully appreciated a clearer understanding of the character of the magnet is at once obtained; it becomes evident that the magnetic effect of the whole is the collective effect (or the sum of the effects) of the parts acting together, the effect of each particle augmenting the effects of the others. Hence the *molecular mode of the orce* becomes at once distinctly apparent. The above illustration, Fig. 26, is from Fownes' Manual of Chemistry.

it will lose altogether its magnetic virtue.* The elevation of temperature and the molecular dilatation consequent upon it, destroys the coercive force and allows the recombination of the magnetic fluid. When after such change the magnet is allowed to cool, it will continue divested of its magnetic qualities. These effects may, however, be again imparted to it by the process already mentioned."

Magnetization of Light and Dia-magnetism.

Encyclopedia Britannica, Chap. III., Sect. III.—"In the year 1845, Dr. Faraday discovered that when magnetic currents, or, as he expresses it, lines of magnetic force, pass through certain bodies, they communicate to these bodies a certain magnetic condition, which, in transparent bodies, is analagous to rotatory double refraction and polarization, and which in other bodies is the reverse of that which takes place in iron, nickel, and some other metals.

If a parallelopiped *N. S. n. s.* of heavy flint glass, 2 inches square and ½ inch thick, and having no action on polarized light, is placed, as in the figure, on the poles *N. S.* of a powerful electro-magnet *N. C. S.*, and a strong galvanic current passed through it in the direction of *S. N.*, the glass will neither be attracted nor repelled, but is found to have received while the current is passing through it, such a structure,† resembling that of quartz and certain fluids, as *to turn the*

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* (1695.) "It appears that a magnetic bar when raised to a red heat does not lose its magnetism suddenly at that temperature." And, when plunged into boiling water and retained there for ten minutes, it loses a part of its magnetism, and if again replunged another portion, and so on but still retaining a portion after seven or eight immersions.

It is not quite apparent whether Sir D. Brewster means by this statement that an alteration or modification in the arrangement of the material particles of the substance takes place in it whilst under the influence of the magnet; supposing the expression of such supposition to be intended so, it is not, we opine, supported by the evidence of the experiment. On the contrary, the fact of the immobility of the particles in the solid glass is opposed *plane of a polarized ray* in the same direction as the current. If the polarized ray is transmitted through the upper and under faces *H. G.* no effect whatever is produced. The rotation of the plane of polarization is from *left to right* when the ray enters the face *s. n.* and the observer looks into the face *n. s.*, and from *right to left* when the ray enters *n. s.*, and the observer looks into *s. n.* This is a very remarkable fact, as the direction of rotation is the same in rock-crystal and other bodies through whatever side the light enters.

The intensity of the rotatory-force depends upon the strength of the galvanic current, and upon the length of the piece of glass. When the ray, by reflections at *n.* and *s.* was made to pass *three* or *five* times through the length *n. s.* of the glass, the effect was increased three or five times, just as in rock-crystal it is increased by increasing the thickness of the plate."

Faraday's Biography, by Professor Tyndall.†

Page 84. "He showed that when a polarized ray passed through his heavy glass in a direction parallel to the magnetic lines of force, the relation is a maximum, and that when the direction of the ray is at right angles to the lines of force, there is no rotation at all. He also proved that the amount of the rotation is proportional to the length of the diamagnetic through which the ray passes. He operated with liquids and solutions. Of aqueous solutions he tried 150 and more, and found the power in all of them. He then examined gases; but here all his efforts to produce any sensible action on the polarized beam were ineffectual. He then passed from magnets to currents, enclosing bars of heavy glass, and tubes containing liquids and aqueous solutions within an electro-magnetic helix. A current sent through the helix caused the plane of polarization to rotate, and always *in the direction of the current.* The rotation was reversed when the current was reversed. In the case of magnets, he observed a gradual, though quick, ascent of the transmitted beam from a state of darkness to its maximum brilliancy when the magnet was excited. In the case of currents, the beam attained *at once* its maximum. This

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to the acceptance of such supposition; and, moreover, it is a reasonable inference that any such structural alteration in the matter of the substance would be directly cognizable in other ways, and it is not shown that such structural alteration has been cognized in other ways.

† 'Faraday as a discoverer.'

he showed to be due to the *time* required by the iron of the electro-magnet to assume its full magnetic power, which time vanishes when a current, without iron, is employed. 'In this experiment,' he says, 'we may, I think, justly say that a ray of light is electrified, and the electric forces illuminated.' In the helix, as with the magnets, he submitted *air* to magnetic influence 'carefully and anxiously,' but could not discover any trace of action on the polarized ray."

Page 90. "Before the pole of an electro-magnet, he suspended a fragment of his famous heavy glass; and observed that when the magnet was powerfully excited the glass fairly retreated from the pole. It was a clear case of magnetic *repulsion*. He then suspended a bar of the glass between two poles; the bar retreated when the poles were excited, and set its length *equatorially* or at right angles to the line joining them. When an ordinary magnetic body was similarly suspended, it always set *axially*, that is, from pole to pole. Faraday called those bodies which were repelled by the poles of a magnet, dia-magnetic bodies."

Page 91. "Soon after he had commenced his researches on dia-magnetism, Faraday noticed a remarkable phenomenon which first crossed my own path in the following way: In the year 1849, while working in the cabinet of my friend, Professor Knoblauch, of Marburg, I suspended a small copper coin between the poles of an electro-magnet. On exciting the magnet, the coin moved towards the poles and then suddenly stopped, as if it had struck against a cushion. On breaking the circuit the coin was repelled, the revulsion being so violent as to cause it to spin several times round its axis of suspension. A *silbergroschen* similarly suspended exhibited the same deportment. For a moment I thought this a new discovery; but on looking over the literature of the subject, it appeared that Faraday had observed, multiplied, and explained the same effect during his researches on dia-magnetism. His explanation was based upon his own great discovery of magneto-electric currents. The effect is a most singular one. A weight of several pounds of copper may be set spinning between the electro-magnetic poles: the excitement of the magnet instantly stops the rotation. Though nothing is apparent to the eye, the copper, if moved in the excited magnetic field, appears to move through a viscous fluid; while, when a flat piece of the metal is caused to pass to and fro like a saw between the poles, the sawing of the magnetic field resembles the cutting through of cheese or butter.

This virtual *friction* of the magnetic field is so strong, that copper, by its rapid rotation between the poles, might probably be fused. We may easily dismiss this experiment by saying that the heat is due to the electric currents excited in the copper. But so long as we are unable to reply to the [illegible], 'What is an electric current?' the explanation is only [illegible]. For my own part, I look with profound interest and [illegible] the strange action here referred to."

Magnetic Curves.

Lardner's Natural Philosophy.

1615. "The neutral line and the varying attraction of the parts of the surface of the magnet which it separates may be manifested experimentally [illegible] magnet, whether natural or artificial, be rolled in [illegible]. They will adhere to it, and will collect in two [illegible], separated by a space upon which no filings will appear. The thickness with which the filings are collected will increase as the distance from the space which is free from them is augmented.

This effect as exhibited by a natural magnet of rough and irregular form, is represented in Fig. 456: and as exhibited by an artificial magnet in the form of a regular rod or cylinder whose length is considerable as compared with its thickness, is represented in Fig. 457; the equator being represented by *E. Q.*, and the poles by *A.* and *B.*

Fig. 456.

(1616.) "*Experimental illustration of the distribution of the magnetic force.*—The variation of the attraction of different parts of the magnet may also be illustrated as follows. Let a magnet, whether natural or artificial, be placed under a plate of glass or a sheet of paper, and let iron filings be scattered on the paper or glass over the magnet by means of a sieve, the paper or glass being gently agitated so as to give free motion to the particles. They will be observed to

Fig. 457,

effect a peculiar arrangement, corresponding with and indicating the neutral line or equator and the poles of the magnet, as represented in Fig. 458, where *E. Q.* is the equator, and *A.* and *B.* the poles of the magnet."

Fig. 458

(1617.) " *Varying intensity of magnetic force indicated by a pendulum.*—The varying intensity of the attraction of different parts of the surface of the magnet may be ascertained by presenting such surface to a small ball of iron suspended by a fibre of silk so as to form a pendulum. The attraction of the surface will draw this ball out of the perpendicular to an extent greater or less, according to the energy of the attraction. If the equator of the magnet be presented to it, no at raction will be manifested, and the force of the attraction indicated will be augmented according as the point presented to the pendulum is more distant from the equator and nearer to the pole."

(1618.) " *Curve representing the varying intensity.*—This varying distribution of the attractive force over the surface of a magnet may be represented by a curve whose distance from the magnet varies proportionally to the intensity of this force. Thus, if, in Fig. 459, *E. Q*

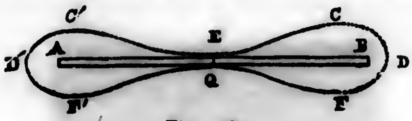
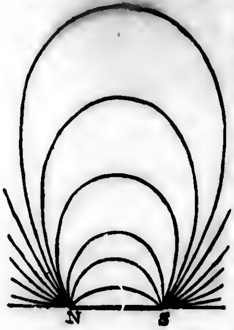


Fig. 459.

be the equator and *A.* and *B.* the poles of the magnet, the curve *E. C. D. F.* may be imagined to be drawn in such a manner that the distance of its several parts from the bar *E. B.* shall be everywhere proportional to the attractive force of the one pole, and a similar curve *E. C. D. F.* will in like manner be proportional to the varying attractions of the several parts of the other pole. These curves necessarily touch the magnet at the equator *E. Q.*, where the attraction is nothing, and they recede from it the more as their distance from the equator increases."

Encyclopedia Britannica, Chapter VIII.



SECT. III. "The general form of the magnetic curves is shown in Fig. 49, where they are seen converging to the two poles *N.* and *S.* of the magnet *N. S.*, and changing their form with their distance from the magnet.

We have already stated that iron filings, arranged by the action of a powerful magnet, afford the finest experimental illustration of the magnetic curves. The best way to do this is to stretch a sheet of paper tightly over a wooden frame, and place it horizontally immediately above a powerful magnet lying on the table. Fine iron filings are now to be shaken through a gauze bag upon the surface of the paper. When the filings are thrown into agitation by gently tapping upon the paper frame, they will dispose themselves into regular lines, stretching from one pole of the magnet to the other, following the course of the magnetic curves and exhibiting them beautifully to the eye.

This effect is shown in the annexed Fig. 50, where *N.* and *S.* are the poles of the magnet *N. S.*, *m.n.* being the mean line where no filings adhere. The same arrangement is also produced when the magnet is held above the paper containing the filings.

In the case of induced magnetism, the steel filings arrange themselves in curves round the iron on which the magnetism is induced, as shown in Fig. 51, where the small bar of iron is in contact with the north pole *N.* of a magnet, *m. n.* being the mean line which separates the two opposite actions of the little iron bar. When the little bar of iron is placed at a distance from the magnet *N.*, as in Fig. 52, the filings arrange themselves as in that figure, *m. n.* being the mean line as before." *

Fig. 51.

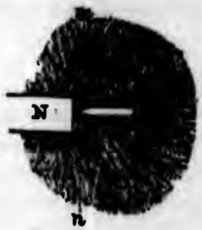
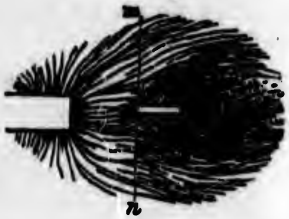


Fig. 52.



Lardner's Natural Philosophy.

(1752.) " *The Electrophorus.*—A small charge of free electricity may by the agency of induction be made to produce a charge of indefinite amount, which may be imparted to any insulated conductor. This is effected by the electrophorus, an instrument consisting of a circular cake, composed of a mixture of shellac, resin, and Venice turpentine, cast in a tin mould, *A. B.*, Fig. 493. Upon this is laid a circular metallic disc *C.*, rather less in diameter than *A. B.*, having a glass handle.

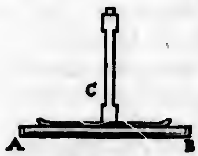


Fig. 493.

Before applying the disc *C.* the resinous surface is electrified negatively by striking it several times with the fur of a cat. The disc *C.* being then applied to the cake *A. B.*, and the finger being at the same time pressed upon the disc *C.* to establish a communication with the ground through the body of the operator, a decomposition takes place by the inductive action of the negative fluid on the resin. The negative fluid escapes from the disc *C.* through the body of the operator to the ground, and a positive charge remains, which is prevented from passing to the resin partly by the thin film of air which will always remain between them—even when the plate *C.* rests upon the resin—and partly by the non-conducting virtue of the resin.

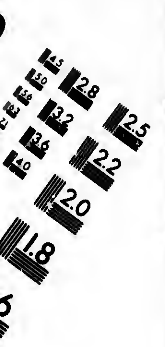
When the disc *C.* is thus charged with positive electricity, kept latent on it by the influence of the negative fluid on *A. B.*, the finger being previously removed from the disc C., let it be raised from the

* For further illustrations of magnetic curves, see Appendix.

resin, and the electricity upon it, before dissimulated, will become free and may be imparted to any insulated conductor adapted to receive it. The charge of negative electricity remaining undiminished on the resin *A. B.*, the operation may be indefinitely repeated; so that an insulated conductor may thereby be charged to any extent, by giving to it the electric fluid drop by drop thus evolved on the disc *C.* by the inductive action of *A. B.*"

Keeping in mind the relationship of the several physical forces as 'forms' or 'modes' of the one primary force, the significance of the result thus obtained by the inductive action of the electrophorus, in connection with the other observed facts of volumetric electricity, may be left to the attentive consideration of the reader without further comment than to note that herein we have a mode of disturbance by which a continuous and inexhaustible supply of free force can be (and is) obtained; inexhaustible, because it consists in a conversion of latent into free force, which, being removed, is replaced from the common reservoir of force, into which, again, that quantity removed from the surface of the material body, must necessarily find its way. . . . It is, therefore, a continuous circulation of force, which force in its circulation is capable of producing by its action, an unlimited amount of effect on material bodies; . . . meaning thereby, an effect in its extent and character proportional only to the quantity and intensity of the force employed, but of which the supply is unlimited.

Having now brought together, from the record, a sufficient number of the natural (observed) facts to illustrate the relationship of the several forms of force; it is desirable to particularly caution the reader with respect to the relation of matter and force. . . . On the one hand, not to invest matter with imaginary properties which do



not belong to it, and, on the other hand, not to confound reasoning by doubting the reality of those properties and characteristics which do belong to matter and things material, and which distinguish it from spirit and things spiritual.

In a scientific sense, *i.e.*, a correct sense, the meaning attached to matter should include all those things which we clearly recognize as belonging distinctively to matter, (*i.e.*, to *that* which is so-called), and should include nothing else; consequently the word 'matter' should be a collective expression for those properties and characteristics of which it consists; and, therefore, to fully and correctly apprehend and describe all those properties and characteristics which pertain to *matter*, is to give a comprehensive and correct definition of the word 'matter.' A dispute, controversy, or argument, as to certain of the properties alleged on the one side and questioned on the other, to belong to *matter*, is a dispute or an argument as to the correct definition of the word, and which definition, if shown to be incorrect or defective, may be amended accordingly. To deny the existence or reality of matter is simple folly; for why should not the word 'matter' be as good as any other word to denote those things or that class of existent things which must be denoted by some collective expression.

But if we are justified in the generalization with respect to the various physical forces which has been now put before the reader, the question then suggests itself, whether matter is not also referable to the primary force, or, in other words, whether matter is not itself a form of force, differing only more essentially from each and all the other forms of force, known to us, than those other forms of force differ from each other.

The supposition being entertained, accordingly, that *matter* is, strictly speaking, a distinct fundamental form of force, differing from that fundamental or collective form which we have denominated Electric Force.

The relationship may be thus formulated:

Free (Electric) Force.	The various Forces (modes or forms of Force) known to physical science.
Materialized Force (or Fixed Force.)	The various descriptions of elementary matter known to chemistry.
Active Force manifested on Matter.	The phenomena of the material world; .... state of motion, gravitation, incandescence, &c., &c.
Latent Force combined with Matter.	The various conditions or molecular states of matter, *i.e.*, the solid, fluid, gaseous condition.

If we adopt this as a theory, or assume it to be an approximately correct explanation, we shall find therein cause to look upon *matter* as particularly connected with ourselves, because entering into our organization as human beings, and appearing to our material senses to constitute *nature.* (Constituting, in fact, that which we *term* nature.) But, viewing the subject in this relationship, we are able to perceive that . . in a spiritual (or universal) sense . . we ought to consider *matter*, (*i.e.*, the material world) as comparatively artificial, by which we mean, as a restricted and limited form of that which is in its primary nature unrestricted and unlimited. Or, to express the same meaning otherwise, we ought to consider that those forces . . . which in a universal or celestial sense may be termed, in their primary condition, *natural* . . . are in the material world materialized and adapted to a particular and limited purpose . . . that purpose including a special restriction within certain definite limits and boundaries, of forces which are in their primary nature unrestricted and unlimited. Both are actually existent ... the spiritual and the material ... and both are consequently real. It would not, therefore, be correct to speak of the one as the shadow of the other; nevertheless, the material reality being derived from and dependent upon the spiritual, and being limited and restricted to certain conditions, the material reality does *represent* the shadow or the reflected image (so to speak) of the unlimited spiritual reality of which it is (may be said to be) a modification. We believe that the form of self-deception or prejudice called 'materialism' has now (in a greater or lesser degree) so strong a hold on the minds of even educated persons that it will, at first, appear to many like stating a paradox to make the assertion that the actual inter-relation of spiritual and natural reality is such that the material world (*i.e.*, matter in its various forms constituting that which we call *nature*,) occupies a relationship to the spiritual world somewhat akin to that which the shadow bears to the substance. We believe that to many this will be calling upon them to reverse their preconceived notions about natural reality; but it necessarily follows that such is the character of the actual relationship between 'material' and 'spiritual' reality, if the explanation we have given of the nature of the physical forces and of matter, be accepted as approximately correct, . . . and we say that, by the rules of sound science, that explanation must necessarily be so accepted.

Note.—To those persons who are desirous to correctly understand this relationship and who find a difficulty in following the argument, we wish to point out the necessity of carefully examining, in the first instance, the precise value of the meaning which they themselves attach to the most prominent terms here made use of, and especially to the words 'nature' and 'matter.' The word 'matter' having been defined, the entire argument or explanation of the subject might be very well put in the form of a definition of the word 'nature,' or, on the other hand, the meaning of the word 'nature' may be restricted and limited to that material sense in which it is usually understood and used, but if so, then, let those who use it in that sense be mindful that its meaning is so restricted, viz., that it is used in a material sense only and not in a general or absolute sense.——

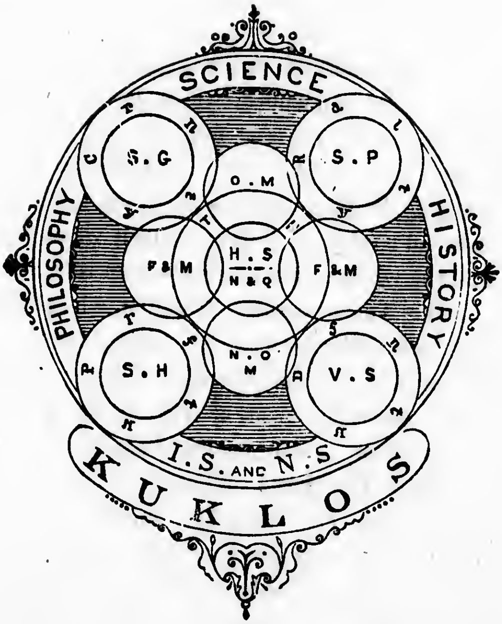
It may assist some persons, perhaps, to suggest the use of the compound terms 'Material-Nature' and 'Spiritual-Nature.' It may be then understood that 'Material-Nature' belongs to a part of creation having a special and distinct purpose; and being, therefore, an adaptation, in which the properties and characteristics of the elementary parts are limited and restricted by special and distinct laws framed expressly for the uniform and harmonious regulation of those parts under the limiting and special conditions to which the material world was to be subjected, it may be apprehended without much difficulty that 'Material-Nature' is, in a more general or spiritual sense, artificial; because it is an adaptation having a special and limited character; nevertheless, be it carefully noted that, all the parts of *this distinct part* of creation (*i.e.*, of the material world, or of 'nature' as usually understood,) are real and true, not only in a material, but also in a spiritual sense.

The plan upon which this distinct part of creation is arranged and the laws by which it is regulated. . . although arbitrary in the sense of limiting and restricting the elementary and compounding parts to the conditions assigned them in the plan, . . . are not to be considered arbitrary in any other sense; there is no reason whatever to infer, and it is not to be inferred, that the reality and truth of the material world are not in harmony with, or that they are not a part of, the reality and truth of the spiritual world.——

We come now to the conclusion of a work which commenced with a reference to the author of the 'great instauration.' The purpose of this our undertaking is in a great measure the same as that which he had in view, namely, to separate sound and wholesome knowledge from the pernicious influence of that corrupt philosophy and unsound knowledge with which it was then, as it is now again becoming more and more, contaminated. Much of his work was almost necessarily, and most advantageously, occupied in teaching the method of scientifically classifying knowledge. . . *i.e.*, of separating and arranging, into an available and useful form, the heterogeneous and disorderly collection of knowledge which at that time obtained. For a long time past this part of

Bacon's system has been fully in use, and it is now well understood and practised; therefore, since it is needless to teach what is already known, the two works will necessarily appear to differ very much in form. We believe, however, that the method adopted will be found on investigation to be essentially the same in both.

However this may be, we know, at least, that the present work has been undertaken and carried out in the same spirit in which we believe that his was accomplished, and we have the same hope and desire that our work will commend itself to the acceptance of those for whose benefit it is intended, which he expressed and doubtless felt. We will, therefore, conclude by expressing, in his words, feelings which we share with him, and by dedicating, in his words, this our work, in reverence, gratitude and confidence, to Him without whose aid and approval the wisdom of the cleverest man is but foolishness..." May Thou, therefore, O Father, who gavest the light of vision as the first fruit of creation, and who hast spread over the fall of man the light of Thy understanding as the accomplishment of Thy works, guard and direct this work, which issuing from Thy goodness, seeks in return Thy glory! When Thou hadst surveyed the works which Thy hands had wrought, all seemed good in Thy sight, and Thou restedst. But when man turned to the works of his hands, he found all vanity and vexation of spirit and experienced no rest. If, however, we labour in Thy works, Thou wilt make us to partake of Thy vision and Sabbath; we, therefore, humbly beseech Thee to strengthen our purpose, that Thou mayst be willing to endow Thy family of mankind with new gifts, through our hands, and the hands of those in whom Thou shalt implant the same spirit."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I.S. AND N.S
KUKLOS

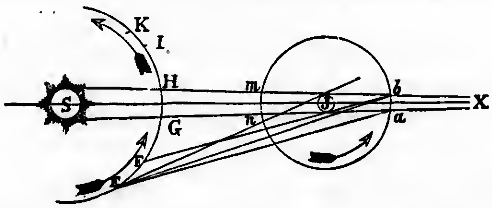
Appendix.

(1.) Eclipses and Occultations of Jupiter's Satellites.

Herschel's Outlines of Astronomy.

(537) "These eclipses (of Jupiter's satellites) moreover, are not seen, as is the case with those of the moon, from the centre of their motion, but from a remote station, and one whose situation with respect to the line of shadow is variable. This, of course, makes no difference in the *times* of the eclipses, but a very great one in their visibility, and in their apparent situations with respect to the planet at the moments of their entering and quitting the shadow."

(538) "Suppose *S.* to be the sun, *E.* the earth in its orbit, *E. F. G. K.*, *J.* Jupiter, and *a.b.* the orbit of one of its satellites. The cone of the shadow, then, will have its vertex at *X.*, a point far beyond the orbits of all the satellites; and the penumbra, owing to the great distance of the



sun, and the consequent smallness of the angle (about 6′ only) its disc subtends at Jupiter, will hardly extend, within the limits of the satellites' orbits, to any perceptible distance beyond the shadow—for which reason it is not represented in the figure. A satellite revolving from west to east (in the direction of the arrows) will be eclipsed when "it enters the shadow at *a.*, but not suddenly, because, like the moon, it has a considerable diameter seen from the planet; so that the time elapsing from the first perceptible loss of light to its total extinction will be that which it occupies in describing about Jupiter an angle equal to its apparent diameter as seen from the centre of the planet, or rather somewhat more, by reason of the penumbra; and the same remark applies to its emergence at *b.* Now, owing to the difference of telescopes and of eyes, it is not possible to assign the *precise* moment of incipient obscuration, or of total extinction at *a.*, or that of the first glimpse of light falling on the satellite at *b.*, or the complete recovery of its light. The observation of an eclipse, then, in which only the immersion, or only the emersion, is seen, is incomplete, and inadequate to afford any precise information, theoretical or practical. But, if both the immersion and emersion can be observed with *the same telescope* and *by the same person*, the interval of the times will give the duration, and their mean the exact middle of the eclipse, when the satellite is in the line *S. J. X.*, *i.e.*, the true moment of its opposition to the sun. Such observations, and such only, are of use for determining the periods and other particulars of the motions of the satellites, and for the calculation of terrestrial longitudes. The intervals of the eclipses, it will be observed, give the synodic periods * of the satellites' revolution; from which their siderial periods must be concluded by the method in art. 418."

(539) "It is evident, from a mere inspection of our figure, that the eclipses take place to the west of the planet, when the earth is situated to the west of the line

* This statement is noteworthy. The inference may be supposed to apply also to the intervals between the commencements of the successive occultations. In either case it is only hypothetically true....on an assumption that the earth remains stationary; for if the earth move to another place in its orbit there must be parallax and alteration in the visual angle.

S.J., *i.e.*, before the opposition of Jupiter; and to the east, when in the other half of its orbit, or after the opposition. When the earth approaches the opposition, the visual line becomes more and more nearly coincident with the direction of the shadow, and the apparent place where the eclipses happen will be continually nearer and nearer to the body of the planet. When the earth comes to *F.*, a point determined by drawing *b.F.* to touch the body of the planet, the *emersions* will cease to be visible, and will thenceforth, up to the time of the opposition, happen *behind* the disc of the planet. Similarly, from the opposition till the time when the earth arrives at *I.*, a point determined by drawing *a. I.* tangent to the eastern limb of Jupiter, the *emersions* will be concealed from our view. When the earth arrives at *G.*, [or *H.*] the immersion [or emersion] will happen at the very edge of the visible disc, and when between *G.* and *H.* [a very small space] the satellites will *pass uneclipsed behind the limb* of the planet."

(540) "Both the satellites and their shadows are frequently observed to *transit* or pass across the disc of the planet. When a satellite comes to *m.*, its shadow will be thrown on Jupiter, and will appear to move across it as a black spot till the satellite comes to *n.* But the satellite itself will not appear to enter on the disc till it comes up to the line drawn from *E.* to the eastern edge of the disc, and will not leave it till it attains a similar line drawn to the western edge. It appears then that the shadow will *precede* the satellite in its progress over the disc *before* the opposition of Jupiter, and *vice versa.*"

(541) "Besides the eclipses and the transits of the satellites across the disc, they may also disappear to us when not eclipsed, by passing behind the body of the planet. Thus, when the earth is at *E.*, the immersion of the satellite will be seen at *a.*, and its emersion at *b.* both to the west

"of the planet, after which the satellite, still continuing its course in the direction *b.*, will pass behind the body and again emerge on the opposite side, after an interval of occultation greater or less according to the distance of the satellite. This interval, (on account of the great distance of the earth compared with the radii of the orbits of the satellites,) varies but little in the case of each satellite, being nearly equal to the time which the satellite requires to describe an arc of its orbit, equal to the angular diameter of Jupiter as seen from its centre, which time, for the several satellites, is as follows: viz., for the first, 2h. 20m.; for the second, 2h. 56m.; for the third, 3h. 43m.; and for the fourth, 4h. 56m.; the corresponding diameter of the planet as seen from these respective satellites being, 19° 49′; 12° 25′; 7° 47′; and 4° 25′. Before the opposition of Jupiter, these occultations of the satellites happen *after* the eclipses: after the opposition when, for instance, the earth is in the situation *K.*, the occultations take place before the eclipses. It is to be observed, that, owing to the proximity of the orbits of the first and second satellites to the planet, *both* the immersion and emersion of either of them can never be observed in any single eclipse, the immersion being concealed by the body, if the planet be past its opposition, the emersion, if not yet arrived at it. So also of the occultation. The commencement of the occultation, or the passage of the satellite behind the disc, takes place while obscured by the shadow, before opposition, and its re-emergence after. All these particulars will be easily apparent on mere inspection of the Figure, Art. 536. It is only during the short time that the earth is in the arc *G. H.*, *i. e.* between the sun and Jupiter, that the cone of the shadow converging (while that of the visual rays diverges) behind the planet, permits their occultations to be completely observed both at ingress and egress, unobscured, the eclipses being then invisible."

APPENDIX.

(2.) The Ether, and the doctrine of Interference.

Tyndall's Lectures on Light. Pages 44 to 50.

" Stand upon the sea-shore and observe the advancing rollers before they are distorted by the friction of the bottom. Every wave has a back and a front, and, if you clearly seize the image of the moving wave, you will see that every particle of water along the front of the wave is in the act of rising, while every particle along its back is in the act of sinking. The particles in front reach in succession the crest of the wave, and as soon as the crest is passed they begin to fall. They then reach the furrow or *sinus* of the wave, and can sink no farther. Immediately afterwards they become the front of the succeeding wave, rise again until they reach the crest, and then sink as before. Thus, while the waves pass onward horizontally, the individual particles are simply lifted up and down vertically. Observe a sea-fowl or, if you are a swimmer, abandon yourself to the action of the waves; you are not carried forward, but simply rocked up and down. The propagation of a wave is the propagation of a form and not the transferrence of a substance which constitutes the wave. The length of the wave is the distance from crest to crest, while the distance through which the individual particles oscillate is called the *amplitude* of the oscillation. You will notice that in this description the particles of water are made to vibrate *across* the line of propagation.

And now we have to take a step forward, and it is the most important step of all. You can picture two series of waves proceeding from different origins through the same water, when, for example, you throw stones into still water, the ring-waves proceeding from the two centres of disturbance intersect each other. Now, no matter how numerous these waves may be, the law holds good that the motion of every particle of the water is the algebraic sum of all the motions im-

"parted to it. If crest coincide with crest, the wave is lifted to a double height; * if furrow coincide with crest, the motions are in opposition, and their sum is zero. We have then still water, which we shall learn presently corresponds to what we call *darkness* in reference to our present subject. This action of wave upon wave is technically called *interference*, a term to be remembered.

Thomas Young's fundamental discovery in optics was that the principle of interference applied to light. Long prior to his time an Italian philosopher, Grimaldi, had stated that, under certain circumstances, two thin beams of light, each of which, acting singly, produced a luminous spot upon a white wall, when caused to act together, partially quenched each other and darkened the spot. This was a statement of fundamental significance, but it required the discoveries and the genius of Young to give it meaning. How he did so, I will now try to make clear to you. You know that air is compressible; that by pressure it can be rendered more dense, and that by dilatation it can be rendered more rare. Properly agitated, a tuning-fork now sounds in a manner audible to you all, and most of you know that the air through which the sound is passing is parcelled out into spaces in which the air is condensed, followed by other spaces in which the air is rarefied. These condensations and rarefractions constitute what we call *waves* of sound. You can imagine the air of a room traversed by a series of such waves, and you can imagine a second series sent through the same air, and so related to the first that condensation coincides with condensation and rarefraction with rarefraction. The consequence of this coincidence would be a louder sound than that produced by either system of waves taken singly. But you can also imagine a state of things where the condensations of the one system fall upon the refractions of the other system. In this case the two systems would completely neutralize each other. Each of them taken singly produces sound; both of them taken together produce no sound. Thus, by adding sound to sound we produce silence, as Grimaldi in his experiment produced darkness by adding light to light.

The analogy between sound and light here at once flashes upon the mind. Young generalized this observation. He discovered a multitude of similar cases, and determined their precise conditions. On

* We have already made an objection (note to page 16) to the teaching in this particular as not according with the known laws of mechanical (physical) science.

"the assumption that light was wave-motion, all his experiments on interference were explained; on the assumption that light was flying particles, nothing was explained. In the time of Huyghens and Euler a medium had been assumed for the transmission of the waves of light, but Newton raised the objection that, if light consisted of the waves of such a medium, shadows could not exist. The waves, he contended, would bend round opaque bodies and produce the motion of light behind them, as sound turns a corner, or as waves of water wash round a rock. It was proved that the bending round referred to by Newton actually occurs,* but that the inflected waves abolish each other by their mutual interference. Young also discerned a fundamental difference between the waves of light and those of sound. Could you see the air through which sound-waves are passing, you would observe every individual particle of air oscillating to and fro in the direction of propagation. Could you see the ether, you would also find every individual particle making a small excursion to and fro, but here the motion, like that assigned to the water-particles above referred to, would be *across* the line of propagation. The vibrations of the air are *longitudinal*, the vibrations of the ether are *transversal*.

It is my desire that you should realize with clearness the character of wave-motion, both in ether and in air. And, with this view, I bring before you an experiment wherein the air-particles are represented by small spots of light. They are parts of a spiral, drawn upon a circle of blackened glass, and, when the circle rotates, the spots move in successive pulses over the screen. You have here clearly set before you how the pulses travel incessantly forward, while the particles that compose them perform oscillations to and fro. This is the picture of a sound-wave, in which the vibrations are longitudinal. By another glass wheel, we produce an image of a transverse wave, and here we observe the waves travelling in succession over the screen, while each individual spot of light performs an excursion to and fro across the line of propagation.

Notice what follows when the glass wheel is turned very quickly. Objectively considered, the transverse waves propagate themselves as before, but subjectively, the effect is totally changed. Because of the retention of impressions upon the retina, the spots of light simply describe a series of parallel luminous lines upon the screen, the length of

* How has this been proved?

these lines marking the amplitude of the vibration. The impression of wave-motion has totally disappeared."

"The most familiar illustration of the interference of sound waves is furnished by the *beats* produced by two musical sounds slightly out of unison. These two tuning-forks are now in perfect unison, and when they are agitated together the two sounds flow without roughness, as if they were but one. But by attaching to one of the forks a two-cent piece, we cause it to vibrate a little more slowly than its neighbour. Suppose that one of them performs 101 vibrations in the time required by the other to perform 100, and suppose that at starting the condensations and rarefactions of both forks coincide. At the 101st vibration of the quickest fork they will again coincide, the quicker fork at this point having gained one whole vibration, or one whole wave upon the other. But a little reflection will make it clear that, at the 50th vibration, the two forks are in opposition; here the one tends to produce a condensation where the other tends to produce a rarefaction, by the united action of the two forks, therefore, the sound is quenched, and we have a pause of silence. This occurs where one fork has gained *half a wave-length* upon the other. At the 101st vibration we have again co-incidence, and, therefore, augmented sound, at the 150th vibration we have again a quenching of the sound. Here the one fork is *three half-waves* in advance of the other. In general terms, the waves conspire when the one series is an *even* number of half-wave lengths, and they are destroyed when the one series is an *odd* number of half-wave lengths in advance of the other.* With two forks so circumstanced, we obtain those intermittent shocks

* In regard to this experiment, we remark that the primary cause of the sound is admitted to be the vibration of the metal fork, the primary cause of the quenching of the sound, also, is admitted to be the unequal number, owing to the variation in the rapidity of the vibrations of the two prongs respectively. It does not appear, therefore, that any proof, or even that any evidence, in favour of the undulatory theory is afforded beyond the negative evidence that the observed fact in this instance is not antagonistic to, or irreconcilable with, the theory. The same remark may be likewise applied to the preceding experiment, which may be termed a very striking subjective illustration of *an explanation*, assisting to make that explanation clearly understood, but which does not afford any demonstration or, even, evidence that the explanation itself is sound, further than showing it to be, in certain particulars, or when regarded from a certain point of view, not antagonistic to the observed phenomena.

of sound separated by pauses of silence, to which we give the name of beats."

Page 54 to 56. "In the undulatory theory, what pitch is to the ear, colour is to the eye. Though never seen, the length of the waves of light have been determined. Their existence is proved *by their effects*, and from their effects also their lengths may be accurately deduced. This may, moreover, be done in many ways, and when the different determinations are compared, the strictest harmony is found to exist between them. The shortest waves of the visible spectrum are those of the extreme violet; the longest those of the extreme red; while the other colours are of intermediate pitch or wave-length. The length of a wave of the extreme red is such that it would require 36,918 of them placed end to end to cover one inch, while 64,631 of the extreme violet waves would be required to span the same distance.

Now, the velocity of light, in round numbers, is 190,000 miles per second. Reducing this to inches, and multiplying the number thus found by 36,918, we obtain the number of waves of the extreme red in 190,000 miles. *All these waves enter the eye and hit the retina at the back of the eye in one second.* The number of shocks per second necessary to the production of the impression of red is, therefore, four hundred and fifty-one millions of millions. In a similar manner, it may be found that the number of shocks corresponding to the impression of violet is seven hundred and eighty-nine millions of millions. All space is filled with matter oscillating at such rates. From every star waves of these dimensions move with the velocity of light like spherical shells outwards. And in the ether just as in the water, the motion of every particle is the algebraic sum of all the separate motions imparted to it. Still, one motion does not blot the other out; or, if extinction occur at one point, it is atoned for at some other point. Every star declares by its light its undamaged individuality, as if it alone had sent its thrills through space.

The principle of interference applies to the waves of light as it does to the waves of water and the waves of sound. And the conditions of interference are the same in all three. If two series of light-waves of the same length start at the same moment from a common origin, crest coincides with crest, sinus with sinus, and the two systems blend together to a single system of double amplitude. If both series start at the same moment, one of them being, at starting, a whole wave-length in advance of the other, they also add themselves together, and we have an augmented luminous effect. Just as in the case of sound, the same occurs when the one system of waves is any *even* number of semi-undulations in advance of the other. But if the one system be half a wave-length, or any *odd* number of half wave-lengths in advance, then the crests of the one fall upon the sinuses of the other; the one system, in fact, tends to *lift* the particles of ether at the precise places where the other tends to depress them; hence, through their joint action the ether remains perfectly still. This stillness of the ether is what we call darkness, which corresponds, as already stated, with a dead level in the case of water."

APPENDIX

TO THE

MANIFESTATIONS OF FORCE.

MAGNETO-ELECTRIC FORCE.

Encyclopedia Britannica, Chap. VII., Sec. III., Art. Magnetism.
--Dr. Roget gives the following interesting account of the phenomena which take place by continuing to agitate the filings when they are arranged as in Fig. 53:

"By continuing to tap upon the paper," says he, "the filings arrange themselves still more visibly into separate lines; but here a curious and perhaps unlooked for phenomenon presents itself. The lines gradually move and recede from the magnet, appearing as if they were repelled instead of attracted, as theory would lead us to expect. This arises from the circumstance, that each particle of iron, or cluster of particles, is thrown up into the air by the shaking of the paper, and while unsupported, immediately turns on its centre, and acquires a position more or less oblique to the plane of the paper. This is shown in Fig. 53, in which *M.* represents a section of the magnet, *P. P.* a section of the paper, and *f. f.* the position of the filaments of iron thrown up into the air. The end of each filament nearest to the magnet is thus turned a little downwards, and the filament falls upon the paper at a point a little more distant than that which it before occupied; and thus, step by step, it moves farther and farther from the magnet, till it reaches the edge of the paper and falls off."

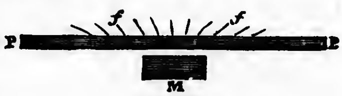


Fig. 53.

"When the magnet, instead of being beneath the paper, is held above it, the effect is just the reverse. In this latter case, the lower ends of the filaments having a tendency to turn towards the magnet, the filings gradually collect under it, when made to dance by the vibrations of the paper, instead of falling outwards as they did before. This will be seen in Fig. 54, where the letters have the same indications as in Fig. 53."

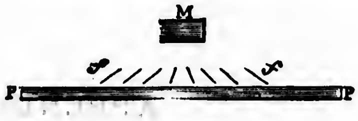
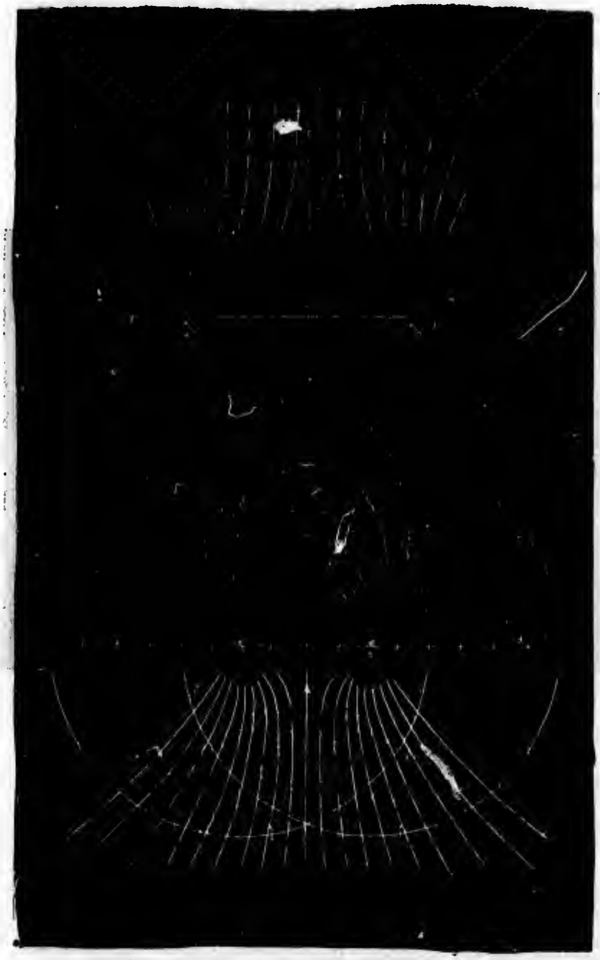


Fig. 54.

"A different set of magnetic curves is produced when two similar poles, for example, two north poles, as shown in Fig. 55, (Pl. 11,) are placed near each other. These curves are called *divergent* curves, and may be exhibited by iron filings like the convergent ones.

Dr Roget has given the following expeditious method of delineating a great number of magnetic curves, related to the same distance between two magnetic poles. He describes from each pole *N. S.*, Fig. 56, as centres, the equal circles or semi-circles *A. A.*, *B. B.*, with as large a radius as the paper will allow; and dividing the axis produced till it meets both circles, he marks off, on the circumference of both circles, the points where they are cut by perpendiculars from these points of division; then drawing radii from the centre of each circle to the divisions of the respective circumferences, the mutual intersections of these radii will give different sets of points indicating the form of the magnetic curves which pass through them. Fig. 56, (Plate 11.) These curves are, in the present case composed, of a succession of diagonals of the lozenge-shaped interstices formed by the intersecting radii, as shown from *convergent* curves in the upper half of the Figure. In the case of *divergent* curves, in Fig. 55, (Pl. 11,) we must take the other diagonals of the lozenge-shaped intervals between the intersecting radii; that is, the diagonals which cross those constituting the convergent curves. This is shown in the lower half of the Figure.

PLATE 11.



MAGNETIC CURVES.

SECT. 11.—*On the mutual action of Magnets.*

When a needle is exposed to the combined action of two magnets, as shown in the annexed Figure, the phenomena, though capable of calculation by the principles already explained, are extremely perplexing and complicated when studied experimentally. Dr. Robison, who first discovered and explained these phenomena, has given such an interesting account of them, that we shall make use of his description of the phenomena, leaving the explanation of them to the next section on magnetic curves.

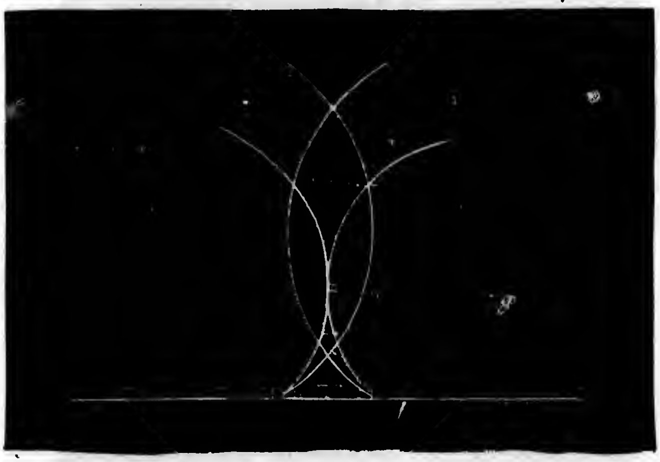


Fig. 46.

"Two large and strong magnets, *A.* and *B.*, were placed with their dissimilar poles fronting each other, and about three inches apart. A small needle, supported on a point, was placed between them at *D.*, and it arranged in the same manner as the great magnets. Happening to set it off to a good distance on the table, as at *F.*, he was surprised to see it immediately turn round on its point, and arrange itself nearly in the opposite direction. Bringing it back to *D.*, restored it to its former position. Carrying it gradually out along *D.F.*, perpendicular to *N.S.*, he observed it to become sensibly more feeble, vibrating more slowly; and when in a certain point, *E.*, it had no polarity whatever towards *A.* and *B.*, but retained any position that was given it. Carrying it farther out, it again acquired polarity to *A.* and *B.*, but in the opposite direction; for it now arranged itself in a position that was parellel to *N. S.* but its north pole was next to *N.* and its south pole to *S.*" * * *

APPENDIX TO ELECTRICAL INDUCTION.

(1734.) "*Development of Electricity by Induction.*—A conductor may be charged with electricity by an electrified body, though the latter shall not lose any of its own electricity or impart any to the conductor so electrified. For this purpose, let the conductor to be electrified be supported on a glass pillar so as to insulate it, and let it then be connected with the ground by a metallic chain or wire. If it be desired to charge it with positive electricity, let a body strongly charged with negative electricity be brought close to it without touching it. On the principle already explained, the negative electricity of the conductor will be repelled to the ground through the chain or wire; and the positive electricity will, on the other hand, be attracted from the ground to the conductor. Let the chain or wire be then removed, and, afterwards, let the electrified body by whose inductive action the effect is produced, be removed. The conductor will remain charged with positive electricity. It may in like manner be charged with negative electricity, by the inductive action of a body charged with positive electricity.*"

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* In this case the conductor connected with the ground and the ground itself should be looked upon as one conductor, so long as they are connected. Therefore, removing the chain or wire cuts off the communication between the one part of the conductor and the other. Rejecting the dual-hypothesis, the explanation will be that the body charged with negative electricity which has been deprived or denuded of its electricity attracts or induces a quantity of electricity to that part of the conductor nearest to it. The chain being removed and the inducing body being afterwards also removed, the electricity accumulated in that part of the conductor (now insulated) is unable to return, and consequently remains in excess of the quantity which naturally or normally (so to speak) belongs to that part of the conductor.

From *Lardner's Natural Philosophy.*

(1745.) "*Reciprocal Inductive Effects of two Conductors.*—If a conductor *A.*, communicating with the ground be placed near another conductor *B.* insulated and charged with a certain quantity of electricity *E.*, a series of effects would ensue by the reciprocal inductive power of the two conductors, the result of which will be augmented in a certain proportion, depending on the distance between the two conductors through which the inductive force acts."

(1747.) "The electricity developed in such cases on the conductor *A.* is subject to the anomalous condition of being incapable of passing away though a conductor be applied to it. In fact, the conductor *A.* in the preceding experiment is supposed to be connected with the earth by conducting matter, such as a chain, metallic column, or wire. Yet the charge of electricity does not pass to the earth as it would immediately do if the conductor *B.* were removed.

In like manner, all that portion of the positive fluid *P.* which is developed on *B.* by the inductive action of *A.* is held there by the influence of *A.* and cannot escape even if the conductors be applied in contact with it."

(1748.) "*Free Electricity.*—Electricity, therefore, which is developed independently of induction, or which being first developed by induction, is afterwards liberated from the inductive action, is distinguished as *free* electricity. In the process above described, that part of the charge *P.* of the conductor *B.* which is expressed by *E.* and which was imparted to *B.* before the approach of the conductor *A.*, is *free*, and continues to be free after the approach of A. If a conductor connected with the earth be brought into contact with *B.*, this electricity *E.* will escape by it; but all the remaining charge of *B.* will remain, so long as the conductor *A.* is maintained in its position. If, however, *E.* be discharged from *B.* the charge which remains will not be capable of retaining in the dissimulated state so great a quantity of negative fluid on *A.* as before. A part will be accordingly set free, and if *A.* be maintained in connection with the ground it will escape. If *A* be insulated it will be charged with it still, but in a free state.

If this free electricity be discharged from *A.* the remaining charge will not be capable of retaining in the latent state so large a quantity of positive fluid on *B.* as previously, and a part of what was dissimulated will accordingly be set free, and may be discharged.

In this manner, by alternate discharges from the one and the other conductor, the dissimulated charges may be gradually liberated and dismissed, without removing the conductor from one another or suspending their inductive action.

APPENDIX TO VOLUMETRIC ELECTRICITY.

From *Fownes' Manual of Chemistry.*

"If glass, amber, or sealing-wax be rubbed with a dry cloth, it acquires the power of attracting light bodies, as feathers, dust or bits of paper; this is the result of a new and peculiar condition of the body rubbed, called electrical excitation.

If a light downy feather be suspended by a thread of white silk, and a dry glass tube, excited by rubbing, be presented to it, the feather will be strongly attracted to the tube, adhere to its surface for a few seconds, and then fall off. If the tube be now excited anew, and presented to the feather, the latter will be strongly repelled.

The same experiment may be repeated with shellac or resin, the feather in its ordinary state will be drawn towards the excited body, and after touching, again driven from it with a certain degree of force.

Now let the feather be brought in contact with the excited glass, so as to be repelled by that substance, and let a piece of excited sealing-wax be presented to it; a degree of attraction will be observed far exceeding that exhibited when the feather is in its ordinary state. Or, again, let the feather be made repulsive for sealing-wax, and then the excited glass presented; strong attraction will ensue.

The reader will at once see the perfect parallelism between the effects described and some of the phenomena of magnetism; the electrical excitement having a two-fold nature, like the opposite polarities of the magnet. A body to which one kind of excitement has been communicated is attracted by another body in the opposite state, and repelled by one in the state same. The excited glass and resin being to each other as the north and south poles of a pair of magnetized bars.

To distinguish these two different forms of excitement, terms are employed, which, although originating in some measure in theoretical views of the nature of the electrical disturbance, may be understood by the student as purely arbitrary and distinctive: it is customary to call the electricity manifested by glass *positive* or *vitreous*, and that developed in the case of shellac, and bodies of the same class, *negative* or *resinous*. The kind of electricity depends in some measure upon the nature of the surface; smooth glass rubbed with silk or wool becomes ordinarily positive, but when ground or roughened by sand or emery, it acquires, under the same circumstances, a negative charge.

The repulsion shown by bodies in the same electrical state is taken advantage of to construct instruments for indicating electrical excitement and pointing out its kind. Two balls of alder-pith, hung by threads or very fine metal wires, serve this purpose in many cases; they open out when excited in virtue of their mutual repulsion, and show by the degree of divergence the extent to which the excitement has been carried.

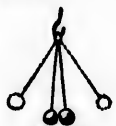


Fig. 58.

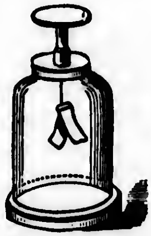


Fig. 59.

A pair of gold leaves suspended beneath a bell-jar, and communicating with a metal cap above, constitute a much more delicate arrangement, and one of great value in all electrical investigations. These instruments are called electroscopes or electrometers; when excited by the communication of a known kind of electricity they show, by an increased or diminished divergence, the state of an electrified body brought into their neighbourhood.

One kind of electricity can no more be developed without the other than one kind of magnetism; the rubber and the body rubbed always assume opposite states, and the positive condition on the surface of a mass of matter is invariably accompanied by a negative state in all surrounding bodies."

The induction of magnetism in soft iron has its exact counterpart in electricity; a body already electrified disturbs or polarizes the particles of all surrounding substances in same manner and according to the same law, inducing a state opposite to its own in the nearer portions, and a similar state in the more remote parts. A series of globes suspended by silk threads, in the manner represented, will each become electric by induction when a charged body is brought near the end of the series, like so many pieces of iron in the vicinity of a magnet, the positive half of each globe looking in one and the same direction, and the negative half in the opposite one. The positive and negative signs are intended to represent the states.

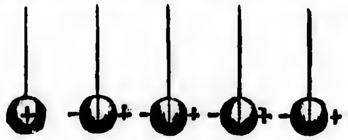


Fig. 60.

The intensity of the induced electrical disturbances diminishes with the distance from the charged body; if this be removed or discharged, all the effects cease at once.

So far, the greatest resemblace may be traced between these two sets of phenomena; but here it seems in a great measure to cease. The magnetic polarity of a piece of steel can awaken polarity in a second piece in contact with it by the act of induction, and in so doing loses nothing whatever of its power; this is an effect completely different from the apparent transfer or discharge of electricity constantly witnessed, which in the air and in liquids often gives rise to the appearance of a bright spark of fire. Indeed, ordinary magnetic effects comprise two groups of phenomena only, those namely of attraction and repulsion, and those of induction. But in electricity, in addition to phenomena very closely resembling these, we have the effects of *discharge*, to which there is nothing analogous in magnetism,* and which takes place in an instant when any electrified body is put in communication with the earth by any one of the class of substances called conductors of electricity; all signs of electrical disturbance then ceasing.

* May not the magneto-electric machine (page 168), wherein the poles of the armature in which the magnetism is induced, are suddenly and continually reversed in front of the magnet, be considered as exhibiting a succession of discharges (of molecular or magnetic electricity)? The wire, in that case, which is coiled an immense number of times around the magnet, would represent, or be analogous to, the condenser and conductor of the volumetric electricity.

These conductors of electricity, which thus permit discharges to take place through their mass, are contrasted with another class of substances called non-conductors or insulators. The difference, however, is only one of degree, not of kind; the very best conductors offer a certain resistance to the electrical discharge, and the most perfect insulators permit it to a small extent. The metals are by far the best conductors; glass, silk, shellac, and dry gas, or vapour of any sort, the very worst; and between these there are bodies of all degrees of conducting power.

Electrical discharges take place silently and without disturbance in good conductors of sufficient size. But if the charge be very intense, and the conductors very small or imperfect, from its nature, it is often destroyed with violence.

When a break is made in a conductor employed in effecting the discharge of a highly excited body, disruptive or spark-discharges, so well known, take place across the intervening air, provided the ends of the conductors be not too distant. The electrical spark itself presents many points of interest in the modifications to which it is liable.

The time of transit of the electrical wave through a chain of good conducting bodies of great length is so minute as to be altogether inappreciable to ordinary means of observation. Professor Wheatstone's very ingenious experiments on the subject give, in the instance of motion through a copper wire, a velocity approaching that of light.

Electrical excitation is *apparent* only upon the surfaces of bodies, or those portions directed towards other objects capable of assuming the opposite state. An insulated ball charged with positive electricity, and placed in the centre of the room, is maintained in that state by the inductive action of the walls of the apartment, which immediately become negatively electrified; in the interior of the ball there is absolutely no electricity to be found, although it may be constructed of open metal gauze, with meshes half an inch wide. Even on the surface the distribution of electrical force will not always be the same: it will depend upon the figure of the body itself, and its position with regard to surrounding objects. The polarity will always be highest in the projecting extremities of the same conducting mass, and greatest of all when these are attenuated to points, in which case the inequality becomes so great that discharge takes place to the air, and the excited condition cannot be maintained.

THE ELECTRICAL MACHINE AND CONDENSER.

The ordinary plate machine, Fig. 62, is thus described by Fownes: "Another form of the electrical machine consists of a circular plate of glass moving upon an axis, and provided with two pairs of cushions or rubbers, attached to the upper and lower parts of the wooden frame, covered with amalgam, between which the plate moves with considerable friction. An insulated conductor, armed as before with points, discharges the plate as it turns, the rubbers being at the same time connected with the ground by the woodwork of the machine, or by a strip of metal."

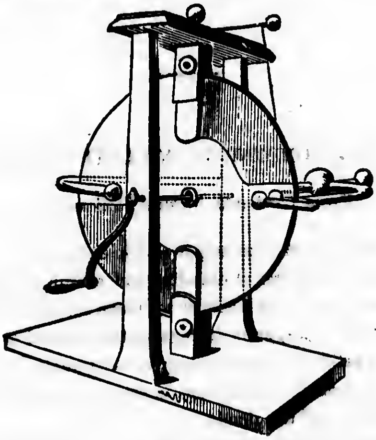
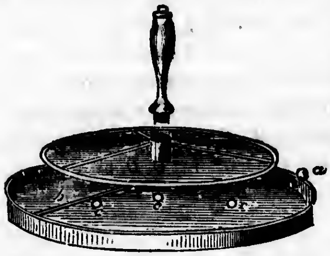


Fig. 62.

The most simple modification of the electrical machine is the electrophorus already mentioned (page 180); another form of the electrophorus is shown at Fig. 11, contrived by Mr. John Phillips, of York, in which the resinous disc is perforated and brass wires c. c.



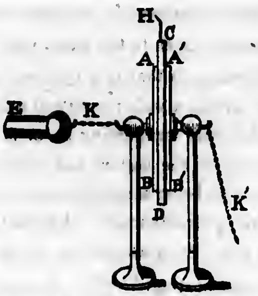
c. in the Fig.) are inserted through the bottom plate and have their ends level with the surface of the resin, so that when the cover is put on, communication between it and the ground is established through the wires. "With ordinary excitation this instrument will yield loud flashing sparks two inches long or more, and speedily charge considerable jars. The cover can be easily charged and discharged fifty or a hundred times in a minute, by merely setting it down and lifting it up as fast as the operator chooses, or the hand can work. In charging a jar or plate, I place one knob on the connecting rod near the insulated surface of the jar or plate, and the other some inches above the cover; then the cover being alternately lifted up and set down, the jar is very quickly charged."

THE CONDENSER AND LEYDEN JAR.

From *Lardner's Natural Philosophy.*

(1759.) "The inductive principle which has supplied the means in the case of the condenser of detecting and examining quantities of electricity so minute and so feeble as to escape all common tests, has placed in the Leyden jar, an instrument at the disposal of the electrician, by which artificial electricity may be accumulated in quantities so unlimited as to enable him to copy in some of its most conspicuous effects the lightning of the clouds.

To understand the principle of the Leyden jar, which at one time excited the astonishment of all Europe, it is only necessary to investigate the effect of a condenser of considerable magnitude placed in connection, not with feeble but with energetic sources of electricity, such as the prime conductor of an electrical machine. In such case it would be evidently necessary that the collecting and condensing plates should be separated by a non-conducting medium of sufficient resistance to prevent the union of the powerful charges with which they would be invested. Let *A. B.*, Fig. 499, represent the collecting plate of such a condenser, connected by a chain *K.* with the conductor *E.* of an electric machine; and let *A'. B'.* be the condensing plate connected by a chain *K.* with the ground. Let *C. D.* be a plate of glass interposed between *A'. B'.* and *A B.*



Let $e.$ express the quantity of electricity with which a superficial unit of the conductor $E.$ is charged. It follows that $e.$ will also express the *free* electricity on every superficial unit of the collecting plate $A. B.$, and of the total charge on each superficial unit of $A. B.$ free and dissimulated, be expressed by $n.$, we shall, according to what has been already explained, have.

$$a = \frac{e}{1 - m^2}$$

"When the machine has been worked until $e.$ ceases to increase, the charge of the plates will have attained its maximum. Let the chains $K.$ and K' be then removed, so that the plates $A. B.$ and $A'. B'.$ shall be insulated, being charged with the quantities of electricity of contrary names expressed by $E.$ and $E.'$"

"In order to divest these principles of whatever is adventitious, and to bring their general character more clearly into view, we have here presented them in a form somewhat different from that in which they are commonly exhibited in electrical experiments. The phenomenon which has just been explained, consisting merely in the communication of powerful charges of electricity of contrary kinds, on the opposite faces of glass or other non-conductor, by means of metal maintained in contact with the glass, it is evident that the form of the glass and of the metal in contact with it, have no influence on the effects. Neither has the thickness or volume of the metal any relation to the results. Thus the glass, whose opposite faces are charged, may have the form of a hollow cylinder or sphere, or of a common flask or bottle, and the metal in contact with it need not be massive or solid plates, but merely a coating of metallic foil.

"1760. *The Leyden Jar.*—In experimental researches, therefore, the

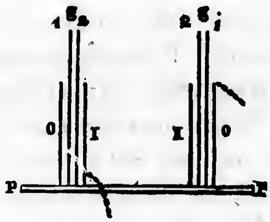
form which is commonly given to the glass, with a view to develop the effects, is that of a cylinder or jar *A. B.*, Fig. 500, having a wide mouth and a flat bottom. The shaded part terminating at *C.* is a coating of tinfoil placed on the bottom and sides of the jar, a similar coating being attached to the corresponding part of the interior surface. A metallic rod, terminating in a ball *D.*, descends into the jar, and is joined (?) in contact with the inner coating." (The flattened base of the rod rests upon the inner coating at the bottom of the jar.)

1763. "*Experimental proof that the charge adheres to the glass and not to the coating.*—The electricity with which the jar is charged in this case resides, therefore, on the glass, or on the conductor by which it passes to the glass, or is shared by these.

To determine where it resides, it is only necessary to provide means of separating the jar from the coating after it has been charged, and examining the electrical state of the one and the other. For this purpose let a glass jar be provided, having a loose cylinder of metal fitted to its interior, which can be placed on it or withdrawn from it at pleasure, and a similar loose cylinder fitted to its exterior. The jar being placed on the external cylinder, and the internal cylinder being inserted in it, let it be charged with electricity by the machine in the manner already described. Let the internal cylinder be then removed, and let the jar be raised out of the external cylinder. The two cylinders being then tested by an electroscopic apparatus, will be found in their natural state. But if an electroscope be brought within the influence of the internal or external surface of the glass jar, it will betray the presence of the one or the other species of electricity. If the glass jar be then inserted in another metallic cylinder made to fit it externally and a similar metallic cylinder made to fit it internally be inserted in it, it will be found to be charged as if no change had taken place. On connecting by metallic communication the interior with the exterior, the opposite electricities will rush towards each other and combine. It is evident, therefore, that the seat of the electricity, when a jar is charged, is not the metallic coating, but the surface of the glass under it."

We do not find any record of this very interesting and instructive experiment having been further pursued. The conclusion here stated does not appear to be demonstrated by the evidence, and it must, for the present at least, be considered questionable and possibly deceptive. By thus gradually withdrawing one metallic cylinder at a time, the effect would be to *transfer* the electricity to the glass vessel by distributing it evenly over the surface thereof. For the purpose of obtaining more decisive evidence the experiment may be thus followed:—(Fig. 501.) Let two loose cylinders of glass, open at both ends, represented at *g*. 1 and 2, in the figure, be placed upright, one inside

Fig. 501.



the other, upon a plate of glass *P.;* and let two cylinders of metal, *I.* and *O.*, not so long as the glass cylinders, be also placed upright on the glass plate, one of them, marked *I.* in the fig., inside the smaller glass cylinder, and the other (metal cylinder), marked *O.*, outside the larger glass cylinder.

The apparatus being thus arranged, let either one of the metal cylinders be made to connect with the earth by a conducting chain attached to it, or in some other suitable manner, and let the other metal cylinder be then charged with electricity; after which, the chain or other connector may be detached. Either one of the glass cylinders may be now removed and tested by the electroscope. If it be found not to have brought with it any of the electricity, it may be replaced and the other glass cylinder may be removed and tested. Should it further appear that the second cylinder had likewise brought away none of the electricity, the first glass cylinder may be then also removed. If the distance between the two metal cylinders is but small and the charge considerable, the electricity will now pass through the air from the one to the other, and they will be thus discharged, but, on the one hand, the distance between the cylinders may be increased, or, the quantity of electricity supplied to the apparatus may be lessened, because a very slight charge would suffice to try the question.* On the supposition that the actual result has not been as yet experimentally ascertained, we opine that the electricity (all of it) will be found, contrary to Dr. Lardner's conclusion, to remain with the metal cylinders.

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* It is here intended for the cylinders to be close together and their sides to be almost in contact, but, we would suggest that, by taking cylinders differing considerably in size, so as to increase the distance between them, some other interesting questions might be in this way submitted to experiment. The material of which the cylinders are composed might be also varied.

Lardner's Natural Philosophy.

(1765.) "*Charging a series of Jars by Cascade.*—In charging a single jar, an unlimited number of jars, connected together by conductors, may be charged with very nearly the same quantity of electricity. For this purpose let the series of jars be placed on insulating stools as represented in Fig. 502, and let *C.* be metallic chains connecting the external coating of each jar with the internal coating of the succeeding one. Let *D.* be a chain connecting the first jar with the conductor of the machine, and *D'.* another chain connecting the last jar with the ground. The electricity conveyed to the inner coating of the first jar *A.* acts by induction on the external coating of the first jar, attracting the negative electricity to the surface, and repelling the positive electricity through the chain *C.* to the inner coating of the second jar. This charge of positive electricity in the second

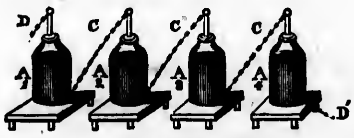


Fig. 50.

jar acts in like manner inductively on the external coating of this jar, attracting the negative electricity there, and repelling the positive electricity through the chain *C.* to the internal coating of the third jar; and in the same manner the internal coating of every succeeding jar in the series will be charged with positive electricity, and its internal coating with negative electricity. If, while the series is insulated, a discharger be made to connect the inner coating of the first with the outer coating of the last jar, the opposite electricities will rush towards each other, and the series of jars will be restored to their natural state.

The word cascade, as used here to denote the movement or transference of the electricity from one jar to the next, belongs to the (material) fluid hypothesis of electricity and is an objectionable mode of expression. Our object, however, in quoting the above case just now, is to suggest that the evidence of this experiment is opposed to the theory of two electricities (or two kinds of electricity) . . . for, how is that theory to be reconciled with the fact here shown? namely, that positive electricity accumulated on the inside (or outside) surface of the one jar is directly connected by the conducting chain with negative electricity accumulated on the outside (or inside) surface of the next jar, and yet the supposed two electricities, having such a powerful attraction each for the other, remain separate and distinct! For example, if we suppose the outside charge of the jar marked *A*. 1, to be negative electricity, then, by the record, the inside charge of the jar *A*. 2, is positive electricity, and between these, communicating with both of them, there is the conducting chain *C*.

The argument may suggest itself as a reply . . . Oh, as to that, . . if you suppose only *one* kind of electricity you are in precisely the same difficulty. But it is not so; . . electricity is communicated, we will suppose, to the interior coating of jar A 1, this having distributed itself over that interior surface acts by induction on the exterior surface, driving out the electricity over the conducting chain into the interior of the next jar, where it distributes itself and acts inductively on the surface of the exterior coating of that jar, as before, and so on. Now this is quite intelligible, because the fact has been established by observation of many other distinct cases that electricity has precisely such inductive action, and the same influence of the free electricity on the one surface which drives out the electricity from the other surface, will evidently, being still free and active, prevent its return, (and this applies to the case of each jar.) It is true that no theoretical reason, based on other and distinct facts can be at present shown why electricity should thus act inductively, it is an observed property or influence belonging to that particular force, and which being known the explanation of the result is quite intelligible. We would remark, in conclusion, that this case, also, does not appear to have received that share of attention, from experimental investigators, which the very interesting and peculiar nature (so to speak) of the phenomenon invites and calls for.

MOLECULAR ELECTRICITY.

The Encyclopedia Britannica.

Voltaic Electricity. —— Sec. IV. *On the production of Light, Heat and Cold by Voltaic Electricity.* — *The Ignition of Wires.* — "It was in England, however, that the calorific and luminous effects of the pile were principally developed. In 1813, the immense battery of the Royal Institution, composed of 2000 couples, and exposing 28,000 square inches, enabled Sir H. Davy to produce light and heat of the highest intensity. When the ends of the wire from each pile terminated in two charcoal points, the most dazzling light passed from the one to the other, and continued for several hours. Steel wires and thin leaves of different metals, were made red hot and burned, and water was boiled by plunging into it an iron wire two feet long and the one-hundredth of an inch in diameter, and placed between the poles of the battery. Platina, sapphire, quartz, lime, &c., when exposed to this source of heat, were instantly melted, and the diamond and charcoal disappeared as if they were completely volatilized. These effects were produced in vacuo as well as in air."

"At the same time that Mr. Children was constructing the greatest voltaic battery ever made, Dr. Wollaston was occupied in constructing the smallest. He took a small thimble, as we have already stated, and having removed the bottom, he flattened the remaining cylinder till its sides were about one-sixth of an inch distant. He then placed between these two surfaces a small plate of zinc which did not touch either side of the thimble. With a platinum wire about one-fortieth of an inch long, and one-three thousandth of an inch in diameter, he united externally the plate of zinc, with this thimble; and when this little galvanic couple was immersed in acidulated water, the platinum wire became red hot, and was melted! This important result led Dr. Wollaston to the valuable conclusion, that in order to obtain powerful calorific effects, we must increase the surface of the copper or negative metal."

"In repeating the experiments of Davy on the light developed by charcoal points, Mr. Brandes discovered that this light, like that of the sun, affected the combination of chlorine and hydrogen, and the decomposition of muriate of silver and other bodies.

"By means of the powerful voltaic battery which Dr. Hare calls a *deflagrator*, and which we have already described, this able chemist obtained some splendid results. A brilliant light, equal to that of the sun, was produced between charcoal points; and plumbago and charcoal were fused * by Professors Silliman and Griscom. By a series of 250, baryta was deflagrated; and a platinum wire, three-sixteenths of an inch in thickness, 'was made to flow like water.' In the experiments with charcoal, the charcoal on the copper side had no appearance of fusion, but a crater-shaped cavity was formed within it, indicating that the charcoal was volatilized at this side, and transferred to the other, where it was condensed and fused, the piece of charcoal at this pile being elongated considerably. This fused charcoal was four times denser than before fusion.

"Owing to its superior conducting power, a continued voltaic current will maintain in a state of incandescence a greater length of silver wire than of platinum or iron; but if we form a wire of short pieces of silver and platinum wire alternately, the platinum portion will become red hot, while the silver ones remain cold. In this case, the current which passes readily along the silver wire, encounters the degree of obstruction in the platinum which produces the red heat. The fact is no doubt connected with the very remarkable one observed by M. Peltier, in the passage of weak currents through metallic circuits,

* This fusion of charcoal and plumbago has not been, we believe, by any means demonstrated. The volatilization of those forms of carbon may be also considered suppositious; conclusive evidence is wanting; these experiments show merely that a superficial disintegration and a partial modification of the solid is effected, and that some of the particles separated by the electric force are transferred from the one electrode to the other.

where *cold* was produced at the points of junction of certain crystallizable metals."

"Liquids, like solids, which are the worst conductors, are the most heated by electrical currents, a result arising from the resistance which the current experiences." *

"While in static electricity, we have the interesting phenomenon of the *electric spark*, already discussed in the article 'Electricity.' We have in voltaic electricity the no less interesting phenomenon of the

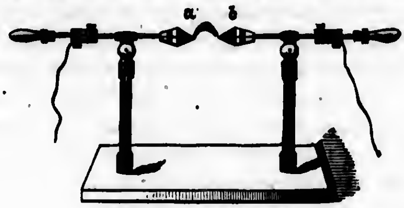


Fig. 56.

voltaic arch, which was discovered by Davy. It is represented at *a. b.* in the annexed figure, as produced between two charcoal points 4 inches distant, transmitting a current from 2000 pairs of zinc and copper, having each a surface of 32 square inches charged with acidulated water. It has the form of an arc convex above, and when the most refractory substances were placed in it, they became incandescent, and disappeared as if by evaporation. When one of the points *a.* was charcoal and the other *b.* plumbago, the particles of charcoal were transferred in the state of vapour to the plumbago, from the positive to the negative pole, and by interchanging the poles the plumbago was transported to the positive pole, as first shown by Dr. Hare.

The appearance and length of the arc varies with the nature of the *electrodes* or points *a. b.* between which it appears. Mr. Grove found that the longest and most brilliant arc, when shown in air, was produced when the electrodes were potassium, sodium, zinc, mercury, iron, tin, lead, antimony, bismuth, copper, silver, gold and platinum, the first giving the largest and brightest arc, and the rest

* This conclusion may be considered *hypothetical*. . .i.e., an opinion based on *hypothesis*; . . . it would be better to say 'a result which appears to be connected with a resistance experienced by the supposed current.'

as in their order. Mr. Grove also observed, that in vacuo the transported matter was in the state of metallic powder when the medium was hydrogen, nitrogen or a vacuum, and an oxide in air or in oxygen."

Sect. V. *On the Chemical Effects of Voltaic Electricity.*

"No sooner was this apparatus made known in England, than Messrs. Nicholson and Carlisle applied it to chemical enquiries. Although Volta had inferred from the shock that the action of the pile was electrical, yet it was to the above enquirers that we are indebted for determining, by means of the revolving doubler, that the *silver* end of the battery was in a *negative* and the *zinc* end in a positive state of electricity. In the course of their experiments, they observed a disengagement of gas which smelt of hydrogen, from water which happened to be in the circuit; and on the 2nd of May, 1800, they discovered that water was decomposed into its elements, viz., oxygen and hydrogen, when the water formed part of circuit between the positive and negative ends of the pile." * * * *

"The attention of our illustrious countryman, Sir H. Davy, was about this time attracted to the subject. So early as 1802, he had made experiments on the chemical agency of the pile; but in 1806, in his first Bakerian Lecture, he was led to the conclusion, *that chemical attraction and repulsion were produced by the same cause, acting in the one case on particles, in the other on masses, and that the same property, under different circumstances, was the cause of all the phenomena exhibited by different voltaic combinations.*"

"With a voltaic battery of 200 plates, he decomposed several of the earths, and discovered their metallic bases, *borium, strontium, calcium* and *magnesium.*"

"In resolving a compound body into its elements, liquidity is an essential condition of the body. A plate of iron, the sixteenth of an inch thick, placed between the two sides of the pile, will stop completely the most powerful electrical current."

"By an irresistible body of evidence, Dr. Faraday has established the important proposition, 'that the chemical power of a current of electriciiy is in direct proportion to the absolute quantity which passes; and this is true of all bodies capable of electro-chemical decomposition. The same eminent philosopher has also deduced, from a variety of facts, the following conclusion: 'that the quantity of electricity, which, being naturally associated with the particles of matter, gives them their combining power, is able, when thrown into a current, to separate these particles from their state of combination; or, in other words, that *the electricity which decomposes and that which is evolved by the decomposition of a certain quantity of matter are alike.*' According to this theory, 'the equivalent weights of bodies are simply those quantities of them which contain equal quantities of electricity, or have naturally equal electric powers, it being the *electricity* which determines the equivalent number, because it determines the combining force; or, if we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalents to each other in their ordinary chemical action, have equal quantities of electricity naturally associated with them."

ACOUSTIC FORCE (SOUND) AND ELECTRICITY.

Encyclopedia Britannica, on the vibratory movements and sounds produced by the Electric Currents.—So early as 1785, the Canon Gottoin, of Como, a friend of Volta's, observed that an iron wire, 30 feet long, when stretched in the open air, emitted a sound in certain states of the atmosphere. Page, Delezenne, Gassiot, and Marienini, observed sounds from electric currents under different circumstances; but it is to Delarive that we owe the most interesting experiments on the subject. When a magnetic but unmagnetized body, such as iron or steel, is placed in the interior of a bobbin, very remarkable rotary movements are produced by discontinuous currents passing through the wire which encircles the bobbin. Two sounds are always distinguished, one a series of blows or shocks, like the noise of rain falling on a metal roof, and the other musical. A mass of iron four inches in diameter, and weighing 22 lbs., placed within a large tube, gave out a very clear and brilliant musical sound; but the most brilliant of all are those obtained by stretching on a sounding-board well-annealed wires from three to six feet long, and one-fifteenth of an inch in diameter."

"A remarkable vibratory motion produced by electricity was observed by Mr. Fearn, of Birmingham, in his electro-gilding establishment. When a brass tube 4 feet long and ½ inch wide in diameter was placed upon, and at right angles to, two horizontal and parallel brass tubes 9 feet long and an inch in diameter, and the latter connected with a strong voltaic battery of from two to twenty pair of large zinc and carbon elements, the transverse tube immediately began to vibrate, and finally to roll upon the other two.

Mr. G. Gore, who repeated the experiment under various circumstances, found that when the resistance was small and uniform, the rolling tube continued to move in the same direction imparted to it; but that when the resistances were not uniform, it continued to roll backwards and forwards as long as the electric current was passing.

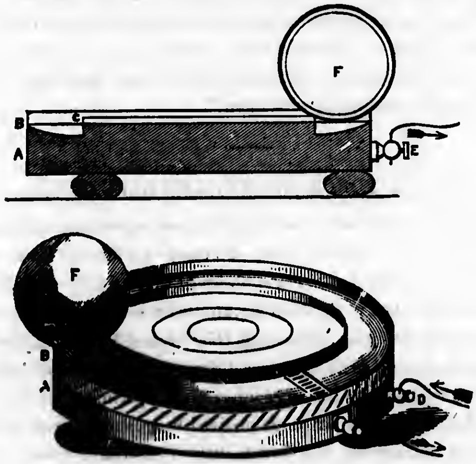


Fig. 57.

In order to obtain a continuous rolling motion, Mr. Gore constructed the apparatus, where *A.* is a circular base of wood provided with two loose rails or hoops, *B.* and *C.* about one thirty-fifth of an inch thick, the outer one being one-fourth of an inch higher than the other, and both being uniform and equidistant. *F.* is a perfectly round thin copper ball, hollow and equally thick, weighing about 500 grains.

When the circular base *A. E.* is made level, the ball *F.* placed upon the rails, and a voltaic current, copious in quantity and moderate in intensity, introduced at the screws *D.* and *E.*, the ball will begin immediately to vibrate, and increase its motions till it revolves upon the rails. It revolves with equal facility in either direction as long as the current is passing, and it becomes much heated during its motion. With three zinc and carbon batteries, the zinc cylinders being 6 inches high and $3\frac{1}{2}$ wide, and strongly charged with dilute sulphuric and strong nitric acids, the ball was propelled at the rate of sixteen revolutions per minute.

'In all cases yet observed,' says Mr. Gore, 'the motion has been attended by a peculiar crackling sound at the surfaces of contact, and by the heating of the rolling metal; and in experiments on a large scale with thick tubes, strong vibrations, accompanied by the emission of musical sounds, were observed similar in a moderate degree to Trevelyan's experiment with heated metals. In a dark place, sparks appeared occasionally at the points of contact.' He considers 'the cause of the motion to be an intermittent thermic action taking place at the surface of contact, at a point a minute distance behind the centre of gravity of the rolling metal.'

Mr. Trevelyan's experiment here referred to consists in placing a heated bar of iron with one end on a solid block of lead. The bar in cooling vibrates considerably, and produces sounds similar to those of an Æolian harp. Prof. Forbes referred this class of vibrations to a repulsive action exercised in the transmission of heat from one body into another, which has a less power of conducting it; but having been led by Mr. Gore's paper to repeat the experiment, by passing an electric current through the hot and cold metal, he found that energetic vibrations took place like those in the ordinary form of the experiment. The vibrations took place whatever was the direction of the electric current, and between metals of the same kind, as well as heterogeneous metals. When a brass bar vibrating on cold lead is heated, and electricity applied as before, the effects are superadded to one another whichever way the current passes, and if there is a musical note it becomes grave. The effect from electricity he considers to be due to the repulsive action of the electricity in passing from the one metal to other, which he regards as a confirmation of his explanation of the calorific vibrations. In extending his experiments, he found that carbon resting upon brass gave very energetic vibrations, and that bismuth is not merely inactive as a vibrator, but during the passage of electricity through it has a quelling power, which brings the vibrating bar to instantaneous rest."

On the physiological effects of Voltaic Electricity.

"A luminous spark is produced by voltaic electricity, when the eye forms part of the circuit. This may be done by placing a piece of silver between the gums and the upper lip, and inserting a silver probe into the nostrils. If a piece of zinc is then laid upon the tongue, and the two metals brought into contact, the flash will be seen."

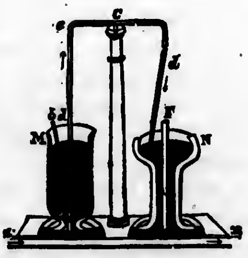
"If a living leech, or an earthworm, is placed upon a crown piece laid upon a piece of zinc of a larger size, it experiences no uneasiness while it touches the silver only, but when it stretches itself and touches the zinc, it instantly draws back as if it had received a shock."

Rotatory dynamical effects of Electro-Magnetism.

"From these experiments, Prof. Oersted concluded *that the magnetical action of the electric current describes circles round* the conductors, and hence he gave the name of revolving magnetism to this magnetical action."

"The action of *revolving magnetism* was at first opposed by Prof. Schweigger, on the ground that if it were true, a magnet might be made to revolve round the uniting wire. Dr. Wollaston drew the same conclusion, but for the purpose of producing such a revolution. Before he had effected his purpose, however, Dr. Faraday went a step further, and found experimentally that not only a magnet could be made to revolve around the uniting wire, but that a moveable uniting wire might be made to revolve round a magnet. An apparatus for exhibiting these remarkable properties is shown in Fig. 66. A wire *a.* from the voltaic battery passes into the glass vessel *M.* through a hole in its bottom, so as to communicate with mercury contained in the vessel. The lower end of a small magnet *b.* of the form of a cylinder, is fixed by a thread to the bottom of the vessel, so that it floats almost vertically in the mercury. A wire *C. c. d.* communicating with the other end of the battery, by means of the brass pillar *C.* dips with its lower end *d.* into the mercury in *M.*, and as soon as the voltaic current is established in the direction of the arrows, *a. d.*, *e. C.*, the pole *b.* of the magnet will revolve round the fixed conductor *d. e. C.*

Fig. 66.



The revolution of the conductor round a magnet is exhibited in the same figure, where *N.* is a glass vessel containing mercury, and having a small cylindrical magnet *F.* fixed to its bottom, aud projecting a little above the surface of the mercury. The wire *d.* being attached by a hook to the horizontal arm *C.* will commence its revolutions round as soon as the voltaic current passes in the direction of the arrows, or *x. F. d. C.* If we make the current pass in the direction *a. d. e. C. F. x.* from the zinc to the platinum end of the battery, both the above revolutions will go on simultaneously. When the current was made to pass in the opposite direction, the direction of the rotation was likewise changed.

"The rotation of liquid conductors may likewise, as Sir H. Davy has shown, be produced by the pole of a magnet. If mercury is placed in a shallow dish between the two poles of a battery, a magnet placed either above or below the mercury, will cause the mercury to revolve round the points from which the currents issue. The rotation of the flame produced by the passage of a powerful voltaic charge between two charcoal points, arises from the same cause. Prof. Daniell gives the following pleasing method of showing the effect. He makes a powerful horseshoe magnet part of the conducting wire of a constant battery of a moderate number of cells; the flame which may then be drawn from one of its poles will revolve in one direction while that from the other will revolve in the opposite direction."

"Various forms have been given to these electrodynamic cylinders. In some the coils all lie in one plane, as in Fig. 71,* where one face of the coil has north, and the other south polarity, the magnetic poles being as it were situated in the centre of each disc.

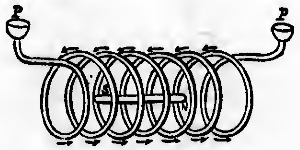


Fig. 72.

When the helix is constructed, as in Fig. 72, its power is so great that a small steel bar *S. N.* placed within it, and supported perpendicularly, will, as soon as the connection is made with the voltaic battery, by means of the mercury cap, *P. p*, start up, and place itself

* See page 220.

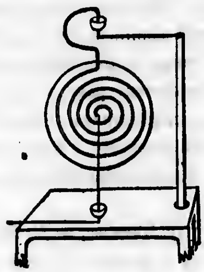


Fig. 71.

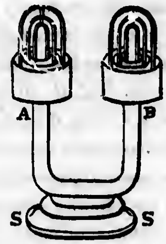


Fig. 74

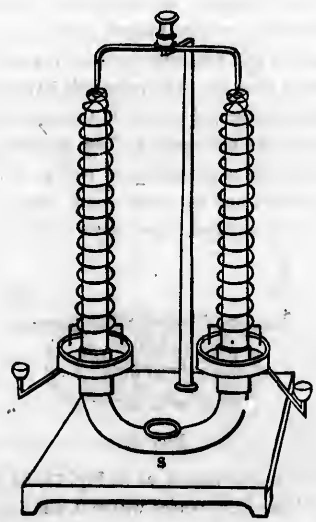


Fig. 77.

"in the air, where, like Mahomet's coffin, it will remain suspended without any visible cause, and in opposition to the power of gravitation.

We owe also to M. Ampere the very interesting apparatus of a small voltaic battery made to revolve round a magnet. This is shown in Fig. 73, where *A. B. C. D. a. b. c. d.* exhibits a section of two cylinders of copper soldered to a copper bottom, so as to hold a fluid. The double cylindrical vessel is suspended by a bent wire *a. F. b.* (having a cavity at *F.*,) upon the north pole *N.* of a vertical magnet *N. S.* A light cylinder of zinc *z. z.* is also so suspended by a bent wire *z. E. z.* and a steel pivot at *E.* upon the same pole N: of the magnet. The cylinder *z. z.* can therefore revolve upon this pivot. When the cylinder *A. B. D. d. b. a. c. C. A.* is filled with dilute acid so as to constitute a small battery, the cylinder *z. z.* will revolve from left to right when *N.* is the north end or south pole, and from right to left when N. is the south end or north pole. Owing to the attraction of the fluid, the cylinder of zinc is often drawn to one side, and prevented from moving; but this may be avoided by making the space *A. c.* sufficiently wide. Mr. Watkins has ingeniously applied this contrivance to the poles of a horse-shoe magnet, as in Fig. 74.* It consists of a horse-shoe magnet *A. B.* fixed to a stand *S. S.* Above each pole is suspended a double cylindrical copper vessel, with a bent metallic wire fixed to the top of the inner cylinder, and a vertical wire, pointed at each extremity, fixed in the middle of the bent wire. The lower ends of the vertical wires of each cylinder rest in the holes of each pole of the magnet. Within the above double copper vessel are placed two hollow cylinders of zinc, having similar bent wires with holes in the lower side of each, in which holes, the upper ends of the vertical wires are inserted. When the copper cylinder is filled with dilute acid, the voltaic action begins, all the four cylinders revolving round their respective axes. The copper cylinders turn slowly and heavily from their weight, in opposite directions to one another and the zinc cylinders, with great velocity, in opposite directions to the copper ones.

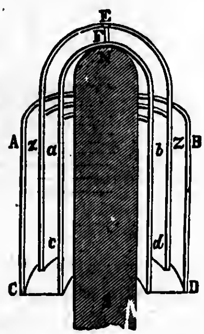


Fig. 73.

* See page 200.

Very delicate suspensions are necessary to ensure the rotation of the copper cylinders.

"A very simple apparatus for shewing the magnetic state of a single coil is shown in Fig. 75, where *Z.* and *C.* represent the elements of a small galvanic battery of one zinc and one copper plate attached to a cork which floats on dilute acid. Each plate is half an inch wide, and two inches long. A piece of copper wire *W.* with silk thread wrapped round it, is bent into a ring, one end of which is soldered to the zinc, and the other to the copper plate.

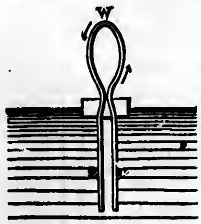


Fig. 75.

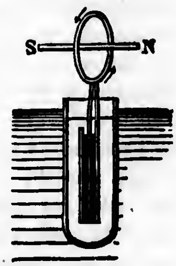


Fig. 76.

An electric current now passes in the direction of the arrow, and the ring *W.* becomes a flat magnet, having its poles in the centre of its two surfaces, the one being north and the other south. This floating magnet will, when acted upon by a real magnet, exhibit the usual magnetic attractions and repulsions. Mr. March has improved this apparatus by doubling the copper plate as in Fig. 76, and converting it into a vessel for holding the dilute acid. The plates are then placed in a glass cylinder which may float in water."

The magneto-electric machine has been greatly improved by Mr. E. M. Clarke, magnetical instrument maker, London. † It is repre- in Fig. 94, where *A.* is the battery of bent bar magnets resting against the vertical board *B.*, and by means of a bar of brass *C.*,

* "A very beautiful apparatus for exhibiting helical rotation has been constructed by Mr. Watkins, and is shown in Fig. 77." It is thought that the figure will for the present purpose sufficiently explain itself as a modification of those preceding it.

† This improved form of the M. E. machine may be compared with that already illustrated at page 168 from Fownes' Manual of Chemistry. The illustration is repeated on the same plate at Fig. 96.

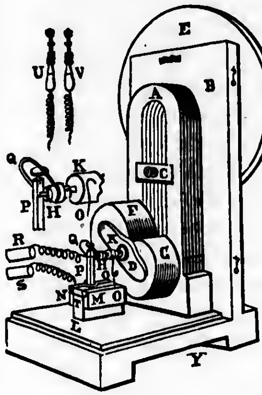


Fig. 94.

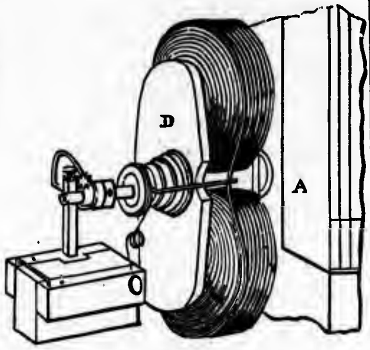


Fig. 95.

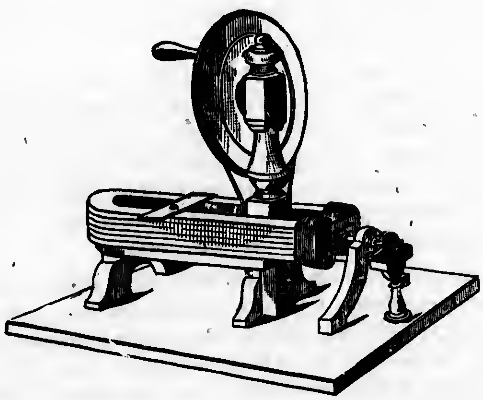


Fig. 96.

" with a bolt and screw-wheel, the magnets can be drawn firmly to the board *B.* or taken from it. One of the keepers or armatures *D.* is screwed into a brass mandrill between the poles of the magnets, and it is made to revolve by the multiplying wheel *E.* This armature has two coils of fine copper wire, 1500 yards long, wrapped round its cylinders, the beginning of each coil being soldered to the armature *D.* from which also projects a brass stem carrying the break-piece *H.*, which can be fastened in any required position by a binding screw; a hollow brass cylinder *K.*, to which the ends of the coils are soldered, being insulated by means of a piece of hard wood attached to the brass stem. An iron wire spring *O.* passes at one end against the cylinder *K.*, and is kept in contact with it by a screw in a brass strap *M.* in the wooden block *L.* A square brass pillar *P.* fits also a square opening in the other brass strap *N.*, on the other side of the block *L.* A metallic spring *Q.* rubs gently upon the break piece H., and is retained in perfect metallic contact with it by a screw in the pillar *P.*, the two straps of brass *M. N.* are connected by a piece of copper wire *T.*, and in this state the parts *D. H. Q. P. N.* are in connection with the commencement of each coil, and the parts *K. O. M.* with the termination of each coil. The perfect metallic contact thus obtained by the spring and break, enables Mr. Clarke to dispense entirely with the use of mercury, which is at all times a troublesome accompaniment of machinery.

" But the great superiority of Mr. Clarke's machine arises from his employing two different armatures, and thus being enabled to produce the separate effects of quantity and intensity to the full extent of the power of his battery. Having, in November, 1834, tried the effects of coils of wire of different thickness, he found that the thick copper bell wire gave brilliant sparks, but no perceptible shock, while very fine wire gave powerful shocks, but very feeble sparks.

By means of the *intensity armature,* which is that shown in Fig. 94 the various experiments made with a number of separate galvanic plates may be performed, while the intense agony produced by its shocks is intolerable: it can, at the same time, (?) electrify the most nervous person without occasioning the least uneasiness. It decomposes water and the neutral salts. It deflects the gold leaves of the electroscope, charges the Leyden jar; and by an arrangement of wires from the mercury box to the battery, the electricity is made visible, "passing from the magnetic battery to the armature, and sparks and brilliant scintillations of steel can be obtained.

The *quantity armature* differs greatly from the intensity one, as shown in Fig. 95, which exhibits the method of producing the spark.

The weight of the iron in the cylinders is much greater than in the intensity one, the copper wire is much thicker, and its length is only forty yards. By this armature all the experiments can be made which are usually performed by a single pair of voltaic plates of large surface, or by a calorimotor; but it will not do for any of the intensity experiments. It produces such large and brilliant sparks, that a person can read small print from the light it produces. It ignites gunpowder and platinum wire, without enclosing the wire in a hermetically sealed glass case. It deflagrates gold and silver leaf, and produces brilliant scintillations from a small steel file. It produces also rotatory motions in delicately suspended wire frames round the poles of a vertical horseshoe magnet and all the other effects of voltaic electricity.

Although the law which governs the evolution of electricity by magneto-electric-induction is very simple, yet Dr. Faraday has found it rather difficult to express it, except in reference to diagrams. We shall therefore give it in his own words: "If in Fig. 89, *P. N.* represent a horizontal wire passing by a marked magnetic pole so that the direction of its motions shall coincide with the curved line proceeding from below upwards; or if its motion parallel to itself be in a line tangential to the curved line, but in the general direction of the arrows; or if it pass the pole in other directions, but so as to cut the magnetic curves* in the same general direction, or on the same side as they would be cut by the wire, if moving along the dotted curved line; then the current of electricity in the wire is from *P.* to *N.* If it be carried in the reverse direction, the electric current will be from *N.* to *P.* Or if the wire be in the vertical position, as at *P.′ N.′*, and

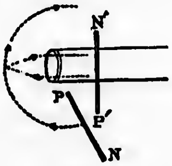


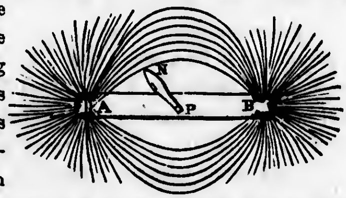
Fig. 89.

* "By magnetic curves, I mean the lines of magnetic force, however modified by the juxtaposition of poles, which would be depicted by iron filings, or those to which a very small magnetic needle would form a tangent."

"it be carried in similar directions, coinciding with the dotted horizontal curve, so far as to cut the magnetic curves on the same side with it, the current will be from *P.'* to *N'*. If the wire be considered a tangent to the curved surface of the cylindrical magnet, and it be carried round that surface into any other position, or if the magnet itself be revolved on its axis, so as to bring any part opposite to the tangential wire; still, if afterwards the wire be moved in the directions indicated, the current of electricity will be from *P.* to *N.*; or if it be moved in the opposite direction, from *N.* to *P.*; so that as regards the motions of the wire past the pole, they may be reduced to two, directly opposite to each other, one of which produces a current from *P.* to *N.* and the other from *N.* to *P.*

The same holds true of the unmarked pole of the magnet, except that if it be substituted for the one in the figure, then, as the wires are moved in the direction of the arrows, the current of electricity would be from *N.* to *P.*, and when they move in the reverse direction from *P.* to *N.*

"Hence the current of electricity which is excited in metal when moving in the neighbourhood of a magnet, depends for its direction altogether upon the relation of the metal to the resultant of magnetic action, or to the magnetic curves, and may be expressed in a popular way, thus: Let *A. B.* (Fig. 90) represent a cylinder magnet, *A.* being the marked pole, and *B.* the unmarked pole; let *P. N.* be a silver knife blade resting across the magnet, with its edge upward, and with its marked or notched side towards the pole *A.*; then in



whatever direction or position this knife be moved edge foremost either about the marked or the unmarked pole, the current of electricity produced will be from *P.* to *N.* provided the intersected curves proceeding from *A.* abut upon the notched surface of the knife, and those from *B.* upon the unnotched side. Or, if the knife be moved with its back foremost, the current will be from *N.* to *P.* in every possible position and direction, provided the intersected curves abut on the same surfaces as before. A little model is easily constructed, by using a cylinder of wood for a magnet, a flat piece for the blade, and a piece of thread connecting one end of the cylinder with the other, and "passing though a hole in the blade for the magnetic curves; this readily gives the result of any possible direction.* When the wire under inducation is passing by an electro-magnetic pole, as, for instance, one end of a copper helix traversed by the electric current, the direction of the current in the approaching wire is the same as that of the current in the parts or side of the spirals nearest to it, and in the receding wire the reverse of that in the parts nearest to it.

All these results show that the power of inducing electric currents is circumferentially exerted by a magnetic resultant, or axis of power, just as circumferential magnetism is dependent on, and is exhibited by, an electric current."

(NOTE.*)—The following clearly expressed statement from *Fowne's Manual of Chemistry*, may enable (or assist) the reader to correctly appreciate the preceding explanation.

"The action which a current of electricity, from whatever source proceeding, exerts upon a magnetized needle, is quite peculiar. The poles or centres of magnetic force are neither attracted nor repelled by the wire carrying the current, but made to move *around* the latter, by a force which may be termed tangential, and which is exerted in a direction perpendicular at once to that of the current, and to the line joining the pole and the wire. Both poles of the magnet being thus acted upon at the same time, and in contrary directions, the needle is forced to arrange itself across the current, so that its axis, or the line joining the poles, may be perpendicular to the wire; and this is always the position which the needle will assume when the influence of terrestrial magnetism is in any way removed. This curious angular motion may even be shown by suspending a magnet in such a way that one only of its poles shall be subjected to the current; a permanent movement of rotation will continue as long as the current is kept up, its direction being changed by altering the pole, or reversing the current. The moveable connections are made by mercury, into which the points of the conducting wires dip. It is often of great practical consequence to be able to predict the direction in which a particular pole shall move by a given current, because in all galvanoscopes, and other instruments involving these principles, the movement of the needle is taken as an indication of the direction of the cir-

"culating current. And this is easily done by a simple mechanical aid to the memory. Let the current be supposed to pass through a watch from the face to the back; the motion of the north pole will be in the direction of the hands, or a little piece of apparatus may be used if reference is often required; this is a piece of pasteboard, or

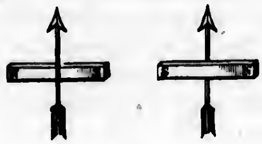


Fig. 68.

other suitable material, cut into the form of an arrow for indicating the current crossed by a magnet having its poles marked, and arranged in the true position with respect to the current. The direction of the latter in the wire of the galvanoscope can at once be known by placing the representative magnet in the direction assumed by the needle itself."

On the Applications of Electro-Magnetism.

Encyclopedia Britannica.—" The power of electric currents to develop magnetism in soft iron is so great as to have led several philosophers to apply it to the production of a continuous movement, either rotatory or reciprocating. M. Jacobi, of St. Petersburg, was the first who constructed such a machine, and it was for a long time used in impelling a boat on the Neva. Since that time many electromotors, as such machines are called, have been constructed; the most important of these are by Loiseau, Froment, Lamanjeau, Page and Dumoncel. The late Mr. Sturgeon pumped water with an electromagnet; Mr. Davidson, of Aberdeen, drove a turning-lathe by the same power; and in 1848 we sailed at the rate of a mile in the hour in a boat thus impelled and constructed by Mr. Dillwyn, of Swansea.

M. Jacobi, as we have stated, has been led by Dr. Faraday's discovery of magnetic electricity to abandon his expectation of obtaining anything like a valuable power from electro-magnetism; and Messrs. Joule and Scoresby have come to the same conclusion. It appears from their calculations that a grain of coal consumed by a steam-engine in Cornwall will raise 143 lb. 1 foot, whilst a grain of zinc consumed in a voltaic battery can raise theoretically only 80 lbs. But the price of an hundred weight of coal is less than 9 pence, whilst that of the same quantity of zinc is more than 216 pence, so that under the most favourable conditions, the power obtained from electro-magnetism must cost twenty-five times as much as that from steam."

Now herein we have a conclusion arrived at on a question of great importance in connection with the progress of civilization in, what may be called, a practical and material sense, as well as in a more highly intellectual sense; an unfavorable conclusion of a very grave and serious practical character, because the mechanical artist or inventor, who at first supposes that out of the resources of nature, a novel means of obtaining his primary power (force), much superior to any hitherto known, has been brought to light and placed in his hands, is checked and not only discouraged, but authoritatively informed it is useless for him to attempt to utilize this novel means, for that—instead of superior—it is very much inferior to the older means already in use, and that the inferiority is not of the character of a difficulty which perseverance and increased skill may, and therefore can overcome, but is a natural inferiority and in the nature of things, insuperable. To the practical (mechanical) artist therefore the following question is of great interest:—Is it quite certain that the decision is a sound one? Is the conclusion supported and justified by the natural facts? To this question we reply that the above conclusion does not appear to us justified and supported by fact. Neither the discoveries of Faraday or of others, properly applied, demonstrate such a proposition, as we opine, but the contrary.

The nature of the calculation cited by the writer in the Encyclopedia, makes apparent that the conclusion has been come to through confounding with each other cases which are essentially different. Thus it is quite true, for instance, if we were to apply molecular electricity to decompose water into its elements, and then make use of the expansive force of the compressed gases thereby disengaged, as a motive (mechanical) power, that the calculation and conclusion would have a sound application to such a proceeding; because it has been ascertained that to develop a certain definite quantity of molecular electricity the consumption of a certain quantity of zinc or other material is requisite, and the definite quantity of the electricity developed can only decompose a limited and definite quantity of water . . a quantity which is directly proportional, in the ratio of the elementary equivalents, to the quantity of the zinc (or other material) consumed in the battery, and therefore the case is quite similar to that of the conversion of water into steam by the combustion of coal; for therein, also, a definite quantity of the coal consumed, developing a definite quantity of caloric force, disengages a proportional quantity of gaseous water, of which the expansive force is available as the primary mechanical power. But in the development and application of electro-magnetism the case is no longer similar. The consumption of a certain definite quantity of zinc will still develop only a definite quantity of molecular electricity as before, but the quantity of mechanical effect which can be obtained from this quantity of electricity through the magnetic power induced by it is not limited in the same manner; . . given a wire conducting molecular electricity, of any intensity,—This wire being coiled around a bar of soft iron induces magnetism therein, but, the greater the number of coils, the greater the intensity of the magnetic force conferred upon the iron; and further, the length of the wire being indefinitely great, it may be coiled around a second bar of iron, and the same electricity which has induced the magnetic power (force) in the first confers also the same property on the second; but, the length of the wire being indefinitely great, instead of two bars we may take ten, or a hundred, or a thousand, or ten thousand, without hindrance by any natural (theoretical) limitation: the electricity is the same in quantity as at first, is just as active, and just as available after having magnetized a hundred bars as after magnetizing one; and again, if the circuit be suddenly broken the (so-called) induced current through the wire in the opposite direction is a source of mechanical power limited only by the length of the wire, which may be indefinitely great. In mechanical science the equality of action and effect as a fundamantal law is very well established, and it is inconsistent with that law to suppose that the quantity of effect can be any greater than the quantity of action (power); for instance, a weight of one pound descending through one foot in one second, represents or develops a certain quantity of mechanical action (power), and this quantity is theoretically capable of producing a quantity of effect precisely equal to itself; but practically, as applied through a machine, a part of the power is employed in overcoming the friction of the moving parts, and the apparently useful effect obtained is always a little less (often much less) than the whole quantity of active power; no combination of levers or refinement of machinery can obtain a quantity of effect greater, in any degree whatever, than the quantity of action (active force) employed.

Now it is very easy to misapprehend the significance of this law and to argue that the utilization of the effect is a use of the active force (action); meaning, thereby, that the force is *used* in the sense of 'used up,' 'consumed,' 'converted' into *effect*. . *i. e.*, into *something else*, and, consequently, is no longer existent as force or power. Such inference is not supported by fact, and is unreasonable. If the descent of one weight is employed in raising another . . the power or force is merely transferred from the first to the second; (it may or may not be equally available for further employment, but it is existent . . all of it, and theoretically available.) So in the steam engine . . the steam having performed its office (produced its mechanical effect) has not necessarily lost any of the caloric-force derived by it, as water, from the combustion of the coal. If all the heat could be now abstracted from the waste steam it might be re-applied to repeat the effect, and so on, for an unlimited number of times. In practice only a small part of the caloric-force (or steam power) can be thus made again available, but even this small part . . namely, that portion of the waste steam used to heat the water supplying the boiler or the air supplying the furnace . . is sufficient to demonstrate the proposition that *action* (meaning thereby *mechanical force* or *power*) is not converted into the equivalent effect, in the sense of being, by such conversion, '*used up*,' and *consumed*.

Mechanical effect is a manifestation of active force overcoming resistance: the resistance having been overcome, the force is no longer active, it becomes quiescent or latent; but, the force is neither lost nor consumed. The great superiority of electro-magnetism as a source of mechanical power consists in its affording the means of obtaining an unlimited number of repetitions of effect from any given quantity of active force. So far from electro-magnetism being unable as a source of motive power to compete with coal, it is quite evident that in such competition the caloric-force derived from coal must be very soon superseded by the much more advantageous and more readily available force of molecular electricity. Let us not forget, however, that the advantages we now enjoy have been gradually obtained by the persistent intellectual labour of our predecessors through many successive generations. It is quite apparent that if we have now arrived at a time when electric force can be, without much difficulty, made directly available for the purposes of civilized life, it is because a certain degree of progress in civilization and in the acquisition of knowledge has been achieved; ..because the human race, albeit waywardly, with many intervals of perverse distrust and ingratitude, have on the whole recognized the leadership of Science, and, from a condition of intellectual darkness, have at length almost emerged into the light of day;.. because we have now learnt to understand and realize that the spiritual and intellectual faculties are superior to the merely animal and material, and that the forces belonging to matter have been made subject to man as a spiritual being. For the earlier stages of human civilization, such as our predecessors have passed through, the enormous benefit of an abundant coal supply could be scarcely over-estimated; it seems, indeed, difficult, on looking back, to imagine such progress to have been, humanly speaking, possible without such a supply of readily available fuel.

Assuming, as we may do, that the use of coal for many of the purposes in which it has been employed will now, ere long, be superseded—it will not be out of place here to remind those of our readers who have paid some attention to the geological record of the earth's history, of the long and careful preparation of that important element of our welfare as a civilized race . . . of the long Carboniferous Period, with its luxuriant vegetation . . . of the teeming and almost numberless successive generations of Lepidodendra and Sagillariæ, by means of which the carbon was taken from the atmosphere and made ready for the final conversion . . . of the long and changeful Permian Period, and. . . of those great disturbances of the earth's surface, belonging to that period, in which the preparation was completed, and the final conversion into beds of coal was consummated.

There have not been wanting some persons of education and partial scientific knowledge who, with a strange forgetfulness of One whose work is not imperfect, and whose plans do not fail, have fearfully predicted the exhaustion of the coal supply, and the consequent collapse of the material prosperity of the civilized world. The Verbal Record states that He who made the heavens and the earth hath also expressly declared that the earth has not been created in vain, and was made to be permanently inhabited. We believe the record and the declaration undoubtingly; and we understand that declaration to include the meaning that ample provision has been or will, when necessary, be made for the continued progressive advancement of (terrestrial) human civilization.

Such fears and predictions are therefore according to our belief not only unreasonable, but also unseemly, and they certainly do not belong to science. There may be indeed, a sufficient basis for fear and apprehension of danger, but if the fear is to be justified by the event and the danger is to become a catastrophe, it will be again, as it has been in former times, occasioned by the wilfulness, the superstition, and intellectual depravity of those who, having acquired knowledge, pervert and misuse it, who, disregarding responsibility and contemning law, systemize untruth and organize deceit.

The coal is not nearly exhausted.

If that deplorable catastrophe, which has already happened more than once, shall yet again overtake mankind . . . if the floods of disorder, anarchy and materialism, are again to overwhelm and destroy the intellectual vitality of the whole human race, and knowledge, escaping only by the providence of the Creator, is again to be left with the elementary rudiments of science, alone to replenish the earth; . . . if the present terrestrial civilization is to be condemned as hopelessly corrupt and thus to share the fate of its predecessors; who shall say there is not sufficient coal, in the vast deposits of this continent only, to supply the necessities of those who, it may be, are destined to renew the attempt to acquire knowledge and with it to acquire the recognition of the responsibilities belonging to knowledge . . . of those who, perhaps, are destined to succeed where we have failed, and to establish on the earth a permanent intellectual civilization, sound, uncorrupt, and possessing the essential requirements for a safe and progressive development.

We do not, however, believe in the intellectual failure of the human race, nor do we expect the destruction of the existing civilization.

That the present is a time for apprehension because a time of critical danger, there can be no reasonable doubt, but, no intellectual catastrophe of a general character will take place unless each and every nation deliberately declares itself by and through the medium of its intellectual representatives as wilfully preferring falsehood to truth, and as determined to disregard the laws of intellectual existence.

That such a determination will be deliberately concurred in by the nation to which we belong, we cannot and do not suppose.