

## **The Problem of Gravitation.\***

BY CHARLES MORRIS.

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Of the varied problems with which modern science has had to deal, that of gravitation has proven the most difficult to solve. While nearly every other agency of nature has in some measure yielded up its secret, as regards this, apparently the most universal of them all, we remain almost completely in the dark. The scope of the problem has been somewhat narrowed, but this is all that can be said. Physicists are satisfied that attraction is but a name for something else, that "action at a distance" does not exist, that some agency unknown is at work upon matter, and even surmise that this agent may be the luminiferous ether. But there they stop, in ignorance of how this agent operates, or how it produces its effect.

It is certainly very probable, in view of the universality of the force of gravitation, that it is dependent upon some simple principle, and possibly this simplicity is the chief cause of its elusive character. There is so little to take hold of, such a lack of those varied elements of action which aid us elsewhere. If, indeed, we could accept attraction as the actual force which many believe it to be, there would be no problem. Newton's law of gravitative action is based on the proposition that every atom in the universe attracts every other atom; the force of attraction being inversely proportional to the square of distance. But Newton accepted attraction only provisionally; as a convenient working tool, not as a credible fact. He expressly says:

"That gravity should be innate, inherent, and essential to matter, so that one body can act upon another at a distance, through a vacuum, without the medium of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I be-

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lieve no man, who has in philosophical matters a competent faculty of thinking, can ever fall into it."

This view of the impossibility of "action at a distance" is widely held by physicists to-day. It is unthinkable to the logical mind that one substance can act upon another through a void, or through space occupied by material that takes no part in the action; as, for an extreme instance, an atom in the sun exercising a pulling force upon one in the earth, by virtue solely of some property dwelling within itself. Recognizing this conclusion as a finality, no matter how small may be the interval between the atoms, all scientists who have attempted to explain gravitation have done so on the basis that the seeming attraction is due to the agency of an external medium, acting through some system of impact, pressure, or tension, stress or strain.

Various hypotheses have been offered in pursuance of this view. In some the active medium is the luminiferous ether; in others it is a special ether confined to this duty alone. Newton suggested the agency of a special medium in some way rarified by material substances, the rarity decreasing outwardly in due proportion to distance. Le Sage invented a system of "ultra-mundane corpuscles," flying in all directions through the universe, impinging forcibly upon the spheres and moving them towards each other. Lord Kelvin imagined an incompressible fluid, filling all space, flowing in from infinity and absorbed by each particle, or momentarily created in each particle and flowing outward to infinity. It is not necessary to go into the details of these hypotheses, or any one demanding a special ether, for none of them is to-day accepted. The tendency now is to look upon the luminiferous ether as in some way the agent at work in gravitation; but in what way remains unknown. A considerable number of hypotheses have been offered in the past few centuries in which gravitation is ascribed to some action of this ether, some of them quite ingenious, but few of these attained even momentary acceptance and none of them is now considered of any potency.

Such is the status of the gravitation problem as it exists to-day. Its scope, as above said, has been narrowed. Gravitative force is believed to be due to some agency of the ether, but

this is as far as anyone has gone. All efforts to show in what this agency consists have failed. This is all, but must it remain all? Is there no clue to the labyrinth? May it not be that the failure so far is the result of a radically false conception of the scope of the problem? Has science put the real nature of the question at issue before it; studied its initial elements before seeking to reach its solution? May not one source of error be the following? In popular acceptation matter, acting through the force of attraction, is the sole active agent in gravitation. In scientific acceptation the ether, or some other universal substance, is the sole active agent. There is no hypothesis in which the possible agency of both matter and ether, each taking a direct part in the issue, is considered. Yet may it not be that matter and ether are jointly active in the process, and that the seeming attraction is the result of conditions of energy directly interacting between these two elements of nature?

Again, gravitation appears to many to stand apart; to have no traceable relation, direct or indirect, with the other forces; to be an isolated phenomenon, which must be dealt with by itself. It is, no doubt, maintained by scientists that all the forces of nature are interrelated, and some hold that there is a close affinity between gravitation and magnetism, but no one has succeeded in demonstrating the existence of such a relation, and so far as we actually know the gravitative force is isolated. Thus the case stands at present; but few physicists doubt that this universal force is definitely related to the other forces of nature, and efforts to find the line of connection have often been made. That they have been so far unsuccessful is no evidence that such a connection does not exist, in view of our ignorance of many of the underlying principles and conditions of nature.

In dealing with the subject of attraction it must be premised that it is not confined to gravitation, but exists also in magnetic, electric, and chemical action. Instead of being a single, it is, in reality, a four-fold phenomenon. But this by no means indicates that there are four separate attractions, unlike the origin and character. Such an idea would infinitely complicate the problem. A single attraction is difficult enough; four undelated forms of attraction would be insuperable. The force we call attraction is in all probability single and simple; an unique phenomenon, not a

composite enigma. That variation in force and method of attraction may arise from variation in conditions is easy to understand; that it arises from primary differences in the force itself is infinitely less probable. We certainly cannot admit this of a peculiar force like attraction unless it be proved that the diversities in its manifestation are irreconcilable. Yet if we view all displays of attraction as due to one general cause, the fact becomes important that attraction does not constitute all we know of electricity and magnetism, as it does in the case of gravitation. Attraction, for instance, is but one among many electric phenomena. It appears to be a temporary one, subject to passing conditions, and a survey of these conditions may throw some light upon the hitherto sealed mystery of gravitation. The path to the unknown leads through the gateway of the known. It is a path that seems never to have been trodden in the present inquiry, but it is one well worth traversing.

It certainly seems a judicious course to study the problem of gravitation at a distance, beginning with the somewhat transparent electric attraction and leading up to the opaque gravitative attraction. This work has been largely done for us in the case of electricity, though no one has carried the effect there visible into the domain of gravitation. A cursory examination of electric attraction seems to render it evident that, in this case at least, attraction does not manifest itself as an inherent property of matter. It comes and goes in response to changes in conditions, and apparently without regard to the matter involved. It may even be transformed into the opposite force of repulsion by a simple reversal of conditions.

We are not aware of what takes place in static electricity, other than that attraction and repulsion appear when the electric state is produced and disappear when electricity is neutralized or conducted away. In current electricity we can with some ease discover a general principle of action. Let us take two metallic wires placed in general parallelism at a moderate distance apart. They do not apparently affect each other. Their gravitative force is too slight to yield any visible result. But if we send currents of electricity through them in the same direction a marked effect appears. They show a tendency to approach, to move together. In common parlance we say that

they attract each other—the seeming attraction aroused being far more powerful than that of gravitation. Reverse one of these currents, cause them to flow in opposite directions, and a new force manifestation appears, that of repulsion. The wires show a tendency to move apart. Cut off the currents and the wires return to the passive state. Every visible indication of attraction of repulsion in them disappears.

We have here a very significant fact in any study of the cause of attractive force. Electric currents seem capable of generating attraction when they move in parallel or accordant directions and repulsion when their directions are reversed. As these forces disappear when the currents are cut off, they may be looked upon as in some way generated by these currents, the part taken in them by matter being, so far as appears, confined to its power of conducting electricity.

It is well to say here that exact parallalism in the conducting wires is by no means necessary, it being simply requisite that the currents should have a general consonance in direction. If the wires form an angle, starting from a common point, and both currents move toward or from this point, attraction will appaers, no matter how wide the angle, even if it be a broadly obtuse one. On the other hand, if one current moves toward, the other from, such an angular point, the wires will repel each other without regard to the width of the angle. The tendency will be to bring the wires into parallel positions and then to draw them together or force them apart as the relations of the currents may demand. All that is requisite in the one case is accordance, in the other discordance, in the direction of the currents.

In seeking to deduce a definite conclusion from these facts, let us take the most recent theory of electricity. This is, that the current is conveyed by electrons the minute constituents of atoms, which fly with extraordinary rapidity from atom to atom, so that practically a swift stream of them flows through the wire. If this theory is correct it gives us some warrant to conclude that attraction and repulsion are dependent upon, not matter in itself, but matter in motion. These forces seem to be in some way generated by moving matter, or movement in matter, attraction by parallel or accordant motions, repulsion by reverse or discordant motions.

The phenomena of magnetism leads us to a similar conclusion. In fact, the magnet can be exactly imitated by sending an electric current through a spirally-wound wire. Two such wires act like two magnets, attracting and repelling, displaying north and south poles. The results are the same as when straight wires are used, the coils attract when their spiral currents flow in parallel directions, repel when their directions are reversed. These electric phenomena are so significant of what is taking place in the interior of magnets that they have led to Ampere's theory, everywhere accepted, that every particle of a magnet has closed currents flowing round it in fixed directions, and that to these currents its attractive and repulsive forces are due. Without going into the details of the magnetic phenomena, the one point with which we are here concerned is that magnetic attraction, like electric, gives very strong indications of being a function of matter in motion, not of matter in itself.

What conclusions shall we draw from all this? While we are ignorant of what takes place in static electricity or in chemical action, the facts of dynamic electricity and of magnetism lead irresistably to the inference that attraction is not an inherent property of matter. It is dependent upon special conditions, and these conditions can be readily so changed that attraction will disappear or will be replaced by repulsion, with no evident change whatever in the character or position of the matter concerned. The one thing necessary for the display of these forces, so far as appears, is the development of special conditions of motion in the material employed.

Here is a fact of extraordinary significance, and one we must take into account in dealing with attraction in any of its manifestations, general and local alike. It is, stated broadly, that attraction is not a property of matter in itself, but arises from a special condition of matter, this condition appearing to be that of motion—not an irregular and constantly reversed motion like that of heat, but a motion in fixed directions, as in the electric current. This inference seems to hold good whether or not we accept the recent theory of electricity. The current may not be due to the motion of electrons, but few doubt that in electric conduction motion of some kind and in some material is taking place, and the appearance of attraction or repulsion seems immediately dependent upon this motion. The

query naturally arises, is gravitative attraction similarly conditioned? Is motion in spherul matter necessary for its manifestation?

This is certainly a very probable conclusion, far more probable than the opposite, that attraction is due to more than one cause and dependent upon more than one condition in matter. It is difficult to imagine that there can be two or more separate causes for so mysterious a force. On the other hand, the condition predicated as necessary is existent in all spherul matter. Motion is everywhere present. The earth, for instance, is circling around the sun at the extraordinary speed of more than eighteen miles a second, and through general space, in company with the whole solar system, at a speed of twelve or more miles per second. The same is true of all spherul bodies, many of them moving with a far greater speed than that named. If now, instead of looking upon the earth as a unit, we regard it as a vast collection of independent atoms, it becomes evident that all its contiguous atoms are rushing in parallel lines with immense rapidity through space. Thus the condition which seems requisite to attraction in local instances is present in the spheres, and we have some justification in assuming that it may be the exciting cause of attraction there also.

To return now to the view so widely entertained, that the luminiferous ether is the active agent in what we call attractive force, let us recall what was above affirmed, that attraction may not be a result of the action of either matter or ether considered separately, but may arise from a close interaction between the two, each playing its part in the result. As to the part taken by matter, we have indications of it in electric and magnetic action. It remains to try if we can discover and co-ordinate or resultant action in ether.

As a preliminary, something must be said about the nature and conditions of ether, so far as known or conjectured. It is held to be an universal substance, occupying all open space and penetrating all the spheres. It is possibly the basis of matter itself, since each atom may be an ether aggregate. Whether it is composed of particles or consists of substance in a state of infinite division; whether it is a plenum, filling all space absolutely, or permits of void intervals; whether it is compressible or incompressible, are questions unanswered, perhaps un-

answerable. We do not know if cohesion exists within it, for the pressure of a plenum may produce the effect of cohesion. We know, from the phenomena of light and other radiations, that it is capable of transmitting vibrations in extraordinary variety and complexity. And the phenomena of light have given rise to the hypothesis that the ether is an electric solid, it being maintained that only a solid could transmit the transverse vibrations of light. To explain the passage of the spheres through solid ether without obstruction the example of an ordinary jelly is adduced. As a weight will sink through a jelly and leave no trace of its passage, so it is held that the spheres can pass freely through the almost infinitely thin jelly of the ether. But the weight does not pass through the jelly without obstruction. Its speed of fall is retarded, and it is hard to avoid the conclusion that the spheres would be similarly retarded by the ether, however thin, if it have such a constitution as here conjectured. Certainly this hypothesis does not appeal to us as probable, however necessary physicists may deem it, and we have before us a problem of very difficult aspect.

We know nothing about the innate constitution of the ether, but from its remarkable readiness to vibrate in response to material impulses we may deduce that it is highly mobile, and are justified in conjecturing that it is a reservoir of intense motor energies and capable of exerting vigorous pressure if these energies are brought to act in one direction. The belief that matter may be derived from the ether is an argument to this effect, since the energies of the ether would then be the source of the very active motions possessed by matter, while energy may be retained much in excess of that given. There are other problems connected with the ether. For instance, is it quiescent or is it adrift through space? Have its particles onward movement or only vibratory or other local motions? This problem is unanswerable, but for our purpose it is simply necessary that the ether should be a storehouse of potent energies.

Returning now to the subject of the relations between ether and matter, it may be said that it has long been a vexed problem how the earth could rush at its immense speed through the ether without obstruction. It was formerly supposed that the earth dashed the ether aside in vast eddies as a ship does the ocean waves. It is now believed that the earth is readily per-



meable to ether, which fills its innumerable pores and drifts through it almost as freely as though no matter were present. But this view merely leaves us confronted with the same problem in a different form. It is simply transferred from the earth as a whole to its constituent atoms. The transfer of the problem from earth to atoms does not change the probable result. The question of obstruction remains the same. The difficulty seems an insuperable one if we hold that the ether is a solid. It is a very awkward one even if we hold that it is an almost infinitely thin gas, especially if this gas be a reservoir of intense energies.

We have now reached a critical point in our inquiry. The problem before us assumes a triple aspect. Does the ether oppose and obstruct the atoms in their swift movement? Does it yield and flow past with no effect upon them? Or does it react upon them in a way differing from that of obstruction? The first of these seems the most probable, but all the evidence goes to prove that it does not exist. The second, while possible, does not appeal to us as probable. The third is a new point of view, never yet taken, but one of great interest, since it may possibly be the missing element in gravitation.

Let us consider the case of a group of atoms moving at a speed of eighteen miles per second through a mass of quiescent but highly mobile ether. In view of the fact that the atoms appear to move without obstruction, we might predict that the ether is non-coherent and therefore non-resistant, and is dashed aside in a broad eddying whirl, curving backward so instantaneously that the atom group is past before its internal energies are brought into play. But the atom group is no more solid than is the earth. It is permeated everywhere with pores, through each of which the ether will drift backward. But if the formation of the ether is disturbed and an eddying movement is produced, it seems probable that it would flow backward more freely outside the group than through its pores, and more freely through its larger than its smaller pores. In other words, if there is a disturbance of the ether formation and interference with its drift through the atom pores, this interference increasing as the pores grow more minute, we should have a degree of rarefac-

tion in these pores, a partial ether vacuum growing more declared as the pores decrease in size. The natural result from this would be a pressure of the external ether similar to that seen when an air vacuum is produced.

The point to be made is this:—If the ether, despite its internal energies, makes no frontal attack upon the atoms, but flows back in unresisting eddies, seeking in preference the larger channels, it seems fair to presume that it may make a lateral attack, crowding the atoms into the spaces in which there is a partial ether vacuum. This is the crux of the situation. If the whirling ether reacts laterally instead of frontally, forcing the atoms inward instead of backward, we are led to an explanation of two mysteries, that of the lack of obstruction to the motion of the spheres and that of the pressure of gravitation. The conceivable former is converted into the actual latter. If the possibility of this be admitted, all forms of attraction will be brought into conformity, that of gravitation coming into harmony with those of magnetism and electricity, to the extent that the motion of matter in each case is the instigating cause.

Such an inward pressure in ether of course would produce condensation, and it might be imagined that the atoms would be driven together until the spaces between them were obliterated and vacuus intervals become impossible. But the atoms have other motions than their spherul ones. Their heat agitation exerts an energy sufficient to keep them permanently apart, despite the gravitative force, and the degree of separation in any case would be the resultant of the opposing forces of external pressure and internal energy.

There is a variation in results between the cases of the movement of a body through air and of a body through ether. The resistance in the former case is due to the cohesion of the air particles. However feeble this be, it would seem likely to cause some resistance, and we know that such a resistance takes place to the motion of meteorites in the exceedingly rare upper atmosphere. The fact, then, that ether makes no resistance seems to indicate that, as above suggested, it is quite destitute of the condition known as cohesion. Its mission may be to produce in other matter the cohesion it lacks in itself.

If there be such a non-coherence, this may be the explanation of its non-sisistance to moving matter ; while its internal energies, and its rarefaction in the pores of moving matter, may be the explanation of the compressing pressure known as attraction of gravitation.

So far we have dealt merely with atom groups and with the very slight pressure exerted upon each of these. Let us now consider the effect upon the sphere as a whole. Its innumerable swarm of atoms, each yielding a minute effect, must in the aggregate yield an immense effect. If the vacua produced in each group of atoms gives rise to an inflow of ether reaching beyond the immediate vicinity, or a pressure making its effect felt for a slight distance outward, then the whole ether impulse would presumably extend to a great distance outward from the earth, the ether moving inward or its energies being directed inward toward the earth throughout a broad field of space. If gravitation is due to this cause, the ether action must extend to and far beyond the sun. In the case of the latter it is supposed to extend to the fixed stars.

In the LeSage hypothesis it is held that the earth and the sun exert an indirect or "shadowing" influence upon each other, each cutting off a part of the stream of corpuscles moving upon the other. The result is held to be a diminished pressure in their connecting line, with the result that the external pressure is the stronger, the effect being to force them toward one another. In the case of an ether pressure, such as we have suggested, the same result would appear. But the present hypothesis suggests a different agency, which may be of still greater effect. The ether between the sun and the earth would be affected by opposing influences and would tend to move in both directions, vigorously toward the sun, more feebly toward the earth. Thus its action toward each orb is resisted by the other and is thus greatly diminished. There must be a limiting zone in which there would be a balance between these tendencies and the ether fail to exert energy in either direction. In this zone the ether, seeking to act in both directions, would tend to thin out or become rarified, a partial vacuum being produced into which both spheres would be forcibly driven by the external pressure. Thus the cutting off of the pressing force of ether from each sphere by the other, thus immensely reduc-

ing its range of action in this line, and the rarefaction of ether between them, would form a double agency forcing them together and holding them in mutual relations of position. If this be the case, the influence of a vacuum must be the active agency not only between atom and atom, but between earth and sun, and perhaps between distant orbs of space.

If the present hypothesis is based on correct premises, and gravitation is a result of the action of moving matter upon ether and the reaction of ether upon matter, there is a very interesting deduction to be made. This is that the force of gravitation must be dependent not upon mass only, as in the Newtonian theory, but upon mass and rapidity of motion combined. For it seems a just conclusion that if the motion of atom groups causes rarefaction of ether within their pores and resultant ether pressure, the rarefaction must increase with increase of speed, and the pressure be correspondingly enhanced. In other words, the force of gravitation must increase with increase of speed in spherul bodies, and the rapidity with which suns and planets move through space would become an important factor in their force of attraction or gravitative energy.

Thus the gravitative force of each planet of our system toward the sun may be dependent only partly upon its mass and largely upon its speed of motion in its orbit. If this be the case, calculations of the mass of a planet based solely upon its gravitative force may be radically false. The same principle would hold good for the great orbs of space. In the case of the extremely swift star known as 1830 Groombridge, the speed of which may be more than two hundred miles per second, there would, under this hypothesis, be a very marked increase in gravity. It is held that such orbs as these have an energy of motion too great for the restraining power of all the orbs in the universe. But if their force of gravity increases with their rate of speed they may be held captive despite their plunging energy. The effect of speed upon gravity is offered here as a suggestion only. It will appear more in the light of a fact when we return to the consideration of electric and magnetic attraction.

There are some minor suggestions to be offered. While the view has been taken that the gravitation of the planets toward the sun depends upon their orbital speed, it must also be re-

membered that the sun and its attendant planets are rushing together through space with a speed estimated at twelve or more miles per second. While this may mainly affect the astral relation of the sun, it may also affect the gravitative energy of the planets and of their satellites. There remains to be considered the axial revolution of the planets. In this the atoms move in parallel lines which should have some gravitative effect. This effect we seem to find in their magnetic energy. The earth, in this way, may be converted into a great magnet, with an energy dependent upon its rotatory speed. If such is the case, each orb of the universe is brought into close analogy with the atom magnet, with its circling motions. The sun, whose equatorial speed or rotation is about four times that of the earth, may possess a much more powerful magnetic force, sufficient, perhaps, to affect some of the planets.

The hypothesis here advanced is not in agreement with the view that the ether is a solid mass. Solidity would require that the ether should possess a force of attraction within itself, a condition which would infinitely complicate the problem of gravitation. The doctrine of ether solidity is based on the fact that the irregular agitation of the particles of a gas would destroy or dissipate transverse vibrations like those of light. But may there not be a condition even of a gaseous ether in which this irregular agitation would not exist sufficiently to disturb the vibrations of light? Under the hypothesis here advanced the ether, even if a very rare gas, would seem to be controlled in its movements, these, instead of being irregular and desultory, being in straight lines toward the spheres; its corpuscles, if such exist, being as rigidly controlled in their movements as though it were a solid mass. Being drawn constantly inward toward the spheres by the vacua existing within them, exerting its pressure, and then drifting away as the spheres pass onward, its movements would be, at least in considerable measure, regular in character, and while not a solid in fact, it might be so in effect. Lines of radiant vibration from sphere to sphere would traverse an ether setting steadily toward these spheres, and the ordinary irregular agitation of gaseous atoms be overcome by the directing and controlling agency here indicated. This would be especially the case if the pressure toward the spheres should give rise to a subsidiary pressure at right

angles to this line of action, the whole body of ether being thus set in motion and controlled in its movements by the one unceasing cause. It is not here intended to maintain that the effect here predicated would be complete, or even large, at a great distance from the sphere, but it may be that even a partial repression of irregular atom motions might suffice to permit the conveyance of light undulations.

Returning to the local forms of attraction, which furnished the clue followed in our study of the spheres, we may seek to apply the hypothesis advanced to these local conditions. The movement of the electric current is now thought to be due to the flight of electrons, passing with immense swiftness from atom to atom, the effect being the same as if a multitude of electrons darted side by side through the whole length of the wire. Here we have to do with a motion of material particles in parallel lines, as in the case of the spheres, and while the electrons are far more minute than atoms, their speed is enormously greater, approximating the extraordinary speed of light. They should therefore profoundly disturb the ether through which they move and produce an ether pressure of far greater energy than that of gravitation. This may be the explanation of the fact that the attraction of two wires conveying electric currents so greatly exceeds the attraction of gravitation between these wires.

In magnetic attraction we have much reason to believe that matter in motion is the agency concerned. The helix, with its current, is simply an artificial magnet, and gives abundant warrant for the Amperian theory that each atom is a minute magnet, its energy being due to closed currents circulating around it, as currents of electricity circulate around the circular curves of the helix. In Ampere's day it was impossible to say more. The theory of the atom then entertained gave no clue to the character of these currents. We can now go much farther. In the recent theory of the atom we have to do with a large number of minute particles, which make up the atom-mass and move with an extraordinary rapidity, their speed being probably many thousands of miles per second. Their mode of motion is unknown, but if we conjecture it to be a circular one, we would have in it the counterpart of Ampere's closed currents. In this case we would possess in each atom an analogue of the

rotating sphere, with its axis and poles and its magnetic force, and the movement of the rotating electrons which make up the atom through the ether in which they float, might well produce pressure like that due to the electric current in the wires, or the atom motions in the spheres. Their immense rapidity would serve to explain the great force of magnetic attraction.

In dealing with electric and magnetic forces we have the phenomena of repulsion as well as that of attraction to consider. How shall this force be explained? While electric attraction demands parallel or accordant currents, repulsion follows reversal of currents, and if the former produces ether rarefaction between the conducting wires, may not the latter produce ether compression? The ether whirls produced by the speeding electrons would meet from opposite directions and tend to heap or condense, exerting a pressure outward in their resumption of normal conditions. In magnetic action the same state of affairs may be looked for. When like poles are brought together their currents of atomic motion would sweep round in opposite directions and the ether whirls to which they gave rise meet in opposition, heaping up and forcibly expanding, thus forcing the magnets apart.

Does a similar force of repulsion act between spheres? It well might do so in the case of the requisite conditions between two spheres. If, for instance, two spheres pass each other in opposite directions, repulsion would be likely, under our hypothesis, to result, if they were close enough together to produce conflicting ether whirls between them. This, however, is a matter upon which it is not safe to decide.

Of the hypothesis here presented it may be said in conclusion that it fulfills the conditions of being simple in principle and universal in operation. Its cause is an unceasing one, since matter and motion are co-eternal verities and ether everywhere present and active. All the substantial contents of the universe are concerned in it, matter and ether alike it depending upon a simple interaction between these two constituents of nature. If the action of the ether suggested be an admissible one all else follows. If it is inadmissible, for any sufficient reason, the whole argument falls to the ground.

## ORIGIN OF SOUTH AFRICA DIAMONDS.

An interesting paper on "The Diamond Pipes and Fissures of South Africa" was recently read before the British Association by H. S. Harger. The author considers that the age of the Orange River Colony pipes is Triassic (late) or Jurassic, and that the Pretoria pipes are contemporaneous. "They are," he said, "the latest eruptives of South Africa." The origin of the blue ground in the pipes he considers due to the sheltering of the ultra basic rocks, such as eclogite, pyroxenite and lherzolite, all of which are commonly met with and are made up of the minerals which form the bulk of the blue ground. In these rocks garnet occurs plentifully and also olivine and pyroxene. The diamond has frequently been found crystallized in garnet and more rarely in olivine; hence the gem must have had its genesis in the ultra-basic zone in which those minerals originated. The experiments of Crookes and Moissan suggest that the presence of iron was necessary for the formation of the diamond; but to this Mr. Harger objected, owing to the fact that the necessary iron does not exist in the diamond mines and also because Dr. Friedlander's experiments proved that diamonds can be formed in olivine without the enormous pressure and heat aimed at by other experimentalists. In conclusion, the author expresses the opinion that the deep-seated, ultra-basic zone, in which garnet and ferro-magnesian silicates predominate, was the medium in which the crystallization of the diamond occurred.—*Eng. and Min. Jour.*

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## FIRE TESTS OF WINDOW GLASS.

Windows and skylights of this material were recently tested at the plant of the British Fire-Prevention Committee. In the window test five squares of wire glass, 3 ft. 3 in. by 4 ft. 6 in., were set in a brick wall, one in a brick frame, two in steel frames and three in brick reveals. The glass was  $\frac{1}{4}$  in. thick. The following details are from *Engineering News*, October 5, 1905. The first lasted for forty-five minutes, with temperatures ranging from 650 deg. F. to 1,540 deg. F.; immediately on lighting the gas the glass in all the openings cracked, particularly around the edges, but beyond the cracks increasing no particular change occurred during the firing. The fire did not pass through the glass. On application of water through a  $\frac{3}{4}$ -in. nozzle under forty-five pounds per square inch pressure, an irregular patch of small holes was made in the upper portion of the center window, which was also bulged inward; otherwise the glass in all the windows remained in position.

In the skylight tests four squares of glass, about 2 by 2 ft., were placed in the roof of the test house so as to be set horizontally. The fire lasted forty-five minutes and reached a temperature of 1,650 deg. F. Immediately on lighting the gas the glass in all four squares cracked in various directions; beyond this no perceptible change occurred during the fire test. Water was applied to the underside of the glass through hose and also poured on the tops of the glass; its effect was to develop hair cracks all over the glass, but no water passed through.—*Iron Age.*