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ON THE FUNDAMENTAL CONCEPTS OF ELECTROSTATICS (QUANTITY, POTENTIAL, CAPACITY, ETC.).[1]

BY PROF. ERNST MACH.

The task has been assigned me to develop before you in a popular manner the fundamental quantitative concepts of electrostatics—"quantity of electricity," "potential," "capacity," and so forth. It would not be difficult, even within the brief limits of an hour, to delight the eye with hosts of beautiful experiments and to fill the imagination with many varied conceptions. But we should, in such a case, be still far from a lucid and easy grasp of the phenomena. The means would still fail us for reproducing the facts accurately in thought—a procedure which for the theoretical and practical man is of equal importance. These means are the *metrical concepts* of electricity.

As long as the pursuit of the facts of a given province of phenomena is in the hands of a few isolated investigators, as long as every experiment can be easily repeated, the fixing of the collected facts by provisional description is ordinarily sufficient. But the case is altered when the whole world must make use of the results reached by many, as happens when the science acquires broader foundations and scope, and particularly so when it begins to supply intellectual nourishment to an important branch of the practical arts, and to draw from that province in return stupendous empirical results. Then the facts must be so described that individuals in all places and at all times can, from a few easily obtained elements, put the facts accurately together in thought, and reproduce them from the description. This is done with the help of the metrical concepts and the international measures.

The work which was begun in this direction in the period of the purely scientific development of the science, especially by Coulomb (1784), Gauss (1833), and Weber (1833), was powerfully stimulated by the requirements of the great technical undertakings manifested since the laying of the first transatlantic cable, and brought to a brilliant conclusion by the labors of the British Association, 1861, and of the Paris Congress, 1881, chiefly through the exertions of Sir William Thomson.

It is plain, that in the time allotted to me I cannot conduct you over all the long and tortuous paths which the science has actually pursued, that it will not be possible at every step to remind you of all the little precautions for the avoidance of error which the early steps have taught us. On the contrary, I must make shift with the simplest and rudest tools. I shall conduct you by the shortest paths from the facts to the ideas, in doing which, of course, it will not be possible to anticipate all the stray and chance ideas which may and must arise from prospects into the by-paths which we leave untrodden.

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Here are two small, light bodies of equal size, freely suspended (Fig. 1), which we "electrify" either

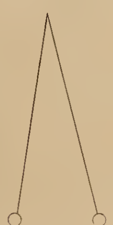

Fig. 1.

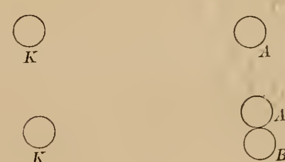

Fig. 2.

by friction with a third body or by contact with a body already electrified. At once a repulsive force is set up which drives the two bodies away from each other in opposition to the action of gravity. This force could accomplish anew the same mechanical work which was expended to produce it.[1]

Coulomb, now, by means of delicate experiments with the torsion-balance, satisfied himself that if the bodies in question, say at a distance of two centimetres, repelled each other with the same force with which a milligramme weight strives to fall to the ground, at half that distance, or at one centimetre, they would repel each other with the force of four milligrammes, and at double that distance, or at four centimetres, they would repel each other with the force

[1] A lecture delivered at the International Electrical Exhibition, in Vienna, on September 4, 1883.

[1] If the two bodies were oppositely electrified they would exert attractions upon each other.

of only one fourth of a milligramme. He found that the electrical force acts inversely as the square of the distance.

Let us imagine, now, that we had some means of measuring electrical repulsion by weights, a means which would be supplied, for example, by our electrical pendulums; then we could make the following observation.

The body A (Fig. 2) is repelled by the body K at a distance of two centimetres with a force of one milligramme. If we touch A, now, with an equal body B, the half of this force of repulsion will pass to the body B; both A and B, now, at a distance of two centimetres from K, are repelled only with the force of one-half a milligramme. But both together are repelled still with the force of one milligramme. Hence, *the division of electrical force* among bodies in contact *is a fact*. It is a useful, but by no means a necessary supplement to this fact, to imagine an electrical fluid present in the body A, with the quantity of which the electrical force varies, and half of which flows over to B. For, in the place of the new physical picture, thus, an old, familiar one is substituted, which moves spontaneously in its wonted courses.

Adhering to this idea, we define the *unit* of electrical quantity, according to the now almost universally adopted centimetre-gramme-second (C. G. S.) system, as that quantity which at a distance of one centimetre repels an equal quantity with unit of force, that is, with a force which in one second would impart to a mass of one gramme a velocity increment of a centimetre. As a gramme mass acquires through the action of gravity a velocity-increment of about 981 centimetres in a second, accordingly, a gramme is attracted to the earth with 981, or, in round numbers, 1000 units of force of the centimetre-gramme-second system, while a milligramme-weight would strive to fall to the earth with approximately the unit force of this system.

We may easily obtain by this means a clear idea of what the unit quantity of electricity is. Two small bodies, K, weighing each a gramme, are hung up by vertical threads, five metres in length and almost weightless, so as to touch each other. If the two bodies be equally electrified and move apart upon electrification to a distance of one centimetre, their charge is approximately equivalent to the electrostatic unit of electric quantity, for the repulsion then holds in equilibrium a gravitational force-component of approximately one milligramme, which strives to bring the bodies together.

Vertically beneath a small sphere suspended from the equilibrated beam of a balance a second sphere is placed at a distance of a centimetre. If both be equally electrified the sphere suspended from the balance will apparently be rendered lighter by the repulsion. If by adding a weight of one milligramme equilibrium be restored, each of the spheres contains in round numbers the electrostatic unit of electrical quantity.

In view of the fact that the same electrical bodies exert at different distances different forces upon one another, exception might be taken to the measure of quantity here developed. What kind of a quantity is that which now weighs more, and now weighs less, so to speak? But this apparent deviation from the method of determination commonly used in practical life, that by weight, is, closely considered, an agreement. On a high mountain a heavy mass also is less powerfully attracted to the earth than at the level of the sea, and if it is permitted us in our determinations to neglect the consideration of level, it is only because the comparison of a body with fixed conventional weights is invariably effected at the same level. In fact, if we were to make one of the two weights equilibrated on our balance approach sensibly to the centre of the earth, by suspending it from a very long thread, as Prof. von Jolly of Munich suggested, we should make the gravity of that weight, its heaviness, proportionately greater.

Let us picture to ourselves, now, two different electrical fluids, a positive and a negative fluid, of such nature that the particles of the one attract the particles of the other according to the law of the inverse squares, but the particles of the same fluid repel each other by the same law; in non electrical bodies let us imagine the two fluids uniformly distributed in equal quantities, in electric bodies one of the two in excess; in conductors, further, let us imagine the fluids mobile, in non-conductors immobile; having formed such pictures, we possess the conception which Coulomb developed and to which he gave mathematical precision. We have only to give this conception free play in our minds and we shall see as in a clear picture the fluid particles, say of a positively charged conductor, receding from one another as far as they can, all making for the surface of the conductor and there seeking out the prominent parts and points until the greatest possible amount of work has been performed. On increasing the size of the surface, we see a dispersion, on decreasing its size we see a condensation of the particles. In a second, non electrified conductor brought into the vicinity of the first, we see the two fluids immediately separate, the positive collecting itself on the remote and the negative on the adjacent side of its surface. In the fact that this conception reproduces, lucidly and spontaneously, all the data which arduous research only slowly and gradually discovered, is contained its advantage and scientific value. With this, too, its value is exhausted. We must not seek in nature for the two hypothetical fluids which we have added as simple mental adjuncts, if we would not go astray. Coulomb's view may be replaced by a totally different one, for example, by that of Faraday, and the most proper course is always, after a general survey is obtained, to go back to the actual facts, to the electrical forces.

We will now make ourselves familiar with the concept of electrical quantity, and with the method of measuring or estimating it. Imagine a common Leyden jar (Fig. 3), the inner and outer coatings of which are connected together by means of two common metallic knobs placed about a centimetre apart. If the inside coating be charged with the quantity of electricity $+q$, on the outer coating a distribution of the electricities will take place. A positive quantity almost equal[1] to the quantity $+q$ flows off to the earth, while a corresponding quantity $-q$ is still left on the outer coating. The knobs of the jar receive their portion of these quantities and when the quantity q is sufficiently great a rupture of the insulating air between the knobs, accompanied with the self-discharge of the jar, takes

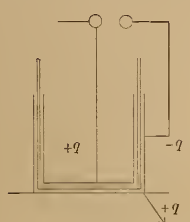

Fig. 3.

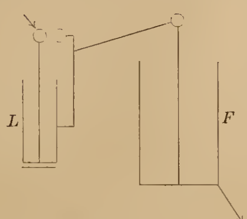

Fig. 4.

place. For any given distance and size of the knobs, a charge of a definite electric quantity q is always necessary for the spontaneous discharge of the jar.

Let us insulate, now, the outer coating of a Lane's unit jar L, the jar just described, and put in connexion with it the inner coating of a jar F exteriorly connected with the earth (Fig. 4). Every time that L is charged with $+q$, a like quantity $+q$ is collected on the inner coating of F, and the spontaneous discharge of the jar L, which is now again empty, takes place. The number of the discharges of the jar L furnishes us, thus, with a measure of the quantity collected in the jar F, and if after 1, 2, 3, . . . spontaneous discharges of L the jar F is discharged, it is evident that the charge of F has been proportionately augmented.

Let us supply now, to effect the spontaneous discharge, the jar F with knobs of the same size and at the same distance apart as those of the jar L (Fig. 5). If we find, then, that five discharges of the unit jar take place before one spontaneous discharge of the jar F occurs, plainly the jar F, for equal distances between the knobs of the two jars, equal striking distances, is able to hold five times the quantity of electricity that L can, that is, has five times the *capacity* of L.[1]

We will now replace the unit jar L, with which we measure electricity, so to speak, *into* the jar F, by a Franklin's pane, consisting of two parallel flat metal plates (Fig. 6), separated only by air. If here, for example, thirty spontaneous discharges of the pane are sufficient to fill the jar, ten discharges will be found sufficient if the air-space between the two plates be filled with a cake of sulphur. Hence, the capacity of a Franklin's pane of sulphur is about three times greater than that of one of the same shape and size made of air, or, as it is the custom to say, the specific inductive capacity of sulphur (that of air being taken as the unit) is about 3.[2] We are here arrived at a very simple fact, which shows us clearly the significance of the number called *dielectric constant*, or *specific inductive capacity*, the knowledge of which is so important for the theory of submarine cables.

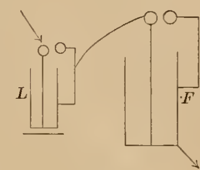

Fig. 5.

Let us consider a jar A, which is charged with a certain quantity of electricity. We can discharge the jar directly. But we can also discharge the jar A (Fig. 7) partly into a jar B, by connecting the two

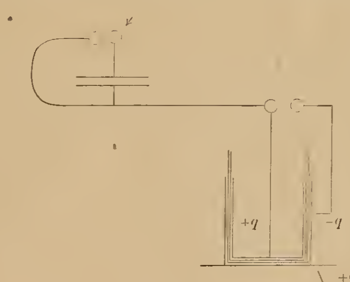

Fig. 6.

[1] The quantity which flows off is in point of fact less than q. It would be equal to the quantity q only if the inner coating of the jar were wholly encompassed by the outer coating.

[1] Rigorously, of course, this is not correct. First, it is to be noted that the jar L is discharged simultaneously with the electrode of the machine. The jar F, on the other hand, is always discharged simultaneously with the outer coating of the jar L. Hence, if we call the capacity of the electrode of the machine E, that of the unit jar L, that of the outer coating of L, A, and that of the principal jar F, then this equation would exist for the example in the text: $(F+A)/(L+E)=5$. A cause of further departure from absolute exactness is the residual charge.

[2] Making allowance for the corrections indicated in the preceding footnote, I have obtained for the dielectric constant of sulphur the number 3.2, which agrees practically with the results obtained by more delicate methods. For the highest attainable precision one should by rights immerse the two plates of the condenser first wholly in air and then wholly in sulphur, if the ratio of the capacities is to correspond to the dielectric constant. In point of fact, however, the error which arises from inserting simply a plate of sulphur that exactly fills the space between the two plates, is of no consequence.

outer coatings with each other. In this operation a portion of the quantity of electricity passes, accompanied by sparks, into the jar *B*, and we now find both jars charged.

It may be shown as follows that the conception of a constant quantity of electricity can be regarded as the expression of a pure fact. Picture to yourself any sort of electrical conductor (Fig. 8); cut it up into a large number of small pieces, and place these pieces by means of an insulated rod at a distance of one centimetre from an electrical body which acts with unit of force on an equal and like-constituted body at the same distance. Take the sum of the forces which this last body exerts on the single pieces of the con-

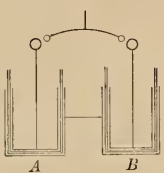

Fig. 7.

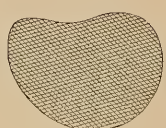
Fig. 8.

ductor. The sum of these forces will be the quantity of electricity on the whole conductor. It remains the same, whether we change the form and the size of the conductor, or whether we bring it near or move it away from a second electrical conductor, so long as we keep it insulated, that is, do not discharge it.

A basis of reality for the notion of electric quantity seems also to present itself from another quarter. If a current, that is, in the usual view, a definite quantity of electricity per second, is sent through a column of acidulated water; in the direction of the positive stream, hydrogen, but in the opposite direction, oxygen is liberated at the extremities of the column. For a given quantity of electricity a given quantity of oxygen appears. You may picture the column of water as a column of hydrogen and a column of oxygen, fitted into each other, and may say the electric current is a chemical current and *vice versa*. Although this notion is more difficult to adhere to in the field of statical electricity and with non-decomposable conductors, its further development is by no means hopeless.

The concept quantity of electricity, thus, is not so aerial as might appear, but is able to conduct us with certainty through a multitude of varied phenomena, and is suggested to us by the facts in almost palpable form. We can collect electrical force in a body, measure it out with one body into another, carry it over from one body into another, just as we can collect a liquid in a vessel, measure it out with one vessel into another, or pour it from one into another.

For the analysis of mechanical phenomena, a metrical notion, derived from experience, and bearing the designation *work*, has proved itself useful. A machine can be set in motion only when the forces acting on it can perform work.

Let us consider, for example, a wheel and axle (Fig. 9) having the radii 1 and 2 metres, loaded respectively with the weights 2 and 1 kilogrammes. On turning the wheel and axle, the 1 kilogramme-weight, let us say, sinks two metres, while the 2 kilogramme-weight rises one metre. On both sides the product

$$\overset{\text{KGR.}}{1} \times \overset{\text{M.}}{2} = \overset{\text{KGR.}}{2} \times \overset{\text{M.}}{1}.$$

is equal. So long as this is so, the wheel and axle will not move of itself. But if we take such loads, or so change the radii of the wheels, that this product (Kgr. × metre) on displacement is in excess on one side, that side will sink. As we see, this product is characteristic for mechanical events, and for this reason has been invested with a special name, *work*.

In all mechanical processes, and as all physical processes present a mechanical side, in all physical processes, work plays a determinative part. Electrical forces, also, produce only changes in which work is performed. To the extent that forces come into play in electrical phenomena, electrical phenomena, be they what they may, extend into the domain of mechanics and are subject to the laws which hold in this domain. The universally adopted measure of work, then, is the product of the force into the distance through which it acts, and in the C. G. S. system, the unit of work is the action through one centimetre of a force which would impart in one second to a gramme-mass a velocity-increment of one centimetre,

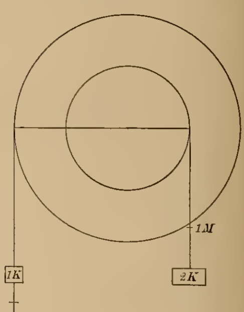

Fig. 9.

that is, in round numbers, the action through a centimetre of a pressure equal to the weight of a milligramme. From a positively charged body, electricity, yielding to the force of repulsion and performing work, flows off to the earth, providing conducting connexions exist. To a negatively charged body, on the other hand, the earth under the same circumstances gives off positive electricity. The electrical work possible in the interaction of a body with the earth, characterises the electrical condition of that body. We will call the work which must be expended on the unit quantity of positive electricity to raise it from the earth to the body *K* the *potential* of the body *K*.[1]

[1] As this definition in its simple form is apt to give rise to misunderstandings, elucidations are usually added to it. It is clear that we cannot lift a

We ascribe to the body K in the C. G. S. system the potential $+1$, if we must expend the unit of work to raise the positive electrostatic unit of electric quantity from the earth to that body; the potential -1, if we gain in this procedure the unit of work; the potential 0, if no work at all is performed in the operation.

The different parts of one and the same electrical conductor in electrical equilibrium have the same potential, for otherwise the electricity would perform work and move about upon the conductor, and equilibrium would not have existed. Different conductors of equal potential, put in connexion with one another, do not exchange electricity any more than bodies of equal temperature in contact exchange heat, or in connected vessels, in which the same pressures exist, liquids flow from one vessel to the other. Exchange of electricity takes place only between conductors of different potentials, but in conductors of given form and position a definite difference of potential is necessary for a spark, that has to pierce the insulated air, to pass between them. [TO BE CONCLUDED.]

quantity of electricity to K, without changing the distribution on K and the potential on K. Hence, the charges on K must be conceived as fixed, and so small a quantity raised that no appreciable change is produced by it. Taking the work thus expended as many times as the small quantity in question is contained in the unit of quantity, we shall obtain the potential. The potential of a body K may be briefly and precisely defined as follows: If we expend the element of work dW to raise the element of positive quantity dQ from the earth to the conductor, the potential of a conductor K will be given by $V = dW/dQ$.

"ACHILLES AND THE TORTOISE."

BY R. N. FOSTER.

In *The Open Court* of September 13 appears a closely reasoned article on the above-named topic, which has long been a source of puzzling interest to students of physics and metaphysics. If the virtue of a puzzle lies in its provoking many to try for its solution, this puzzle of Zeno is of supreme virtue. The names of the great thinkers, who from Aristotle to Mill, have discussed this problem (a few of whom are mentioned in Mr. Shipman's article), are sufficient evidence on this point.

I aim not to disprove what Mr. Shipman has written, but to show that there are other methods than his whereby a solution is possible.

Let me say first that there is no fallacy in the statement (nor any "metaphysics" either) that Achilles cannot overtake the tortoise *on the terms governing the race.*

And secondly, that there is equally no fallacy in saying that Achilles can overtake the tortoise.

Both statements are simply and demonstrably true, and require but a moderate amount of "ciphering" to exhibit the fact.

And finally, for I wish to state all the conclusions first, that my reader may see the goal and follow me to it with clear sight and open eye,—finally, Zeno does not disprove the possibility of motion by his example, but, on the contrary, establishes it, having first assumed it, and then grounded all his argument upon it.

I will ask the reader to sum up in brief terms the three points to be made evident in this paper:

I. Zeno was right. II. Zeno was wrong. III. Zeno proved nothing in either case.

To make it very easy, let us demand that Achilles shall run two miles an hour, and the tortoise one, and that the tortoise shall have one mile the start. Now the terms of the race are wonderfully important—they are the *very essence* of the problem—and they are as follows: When Achilles has run the first mile, he is where the tortoise was when both commenced to run; right at this point, I, the judge, am to decide the result. Well, Achilles is now half a mile behind the tortoise. I mark the position of both, without interrupting the race, which goes merrily on. When Achilles has run this half mile that he lacked at the first marking, the tortoise is a quarter of a mile ahead. When Achilles gains this quarter mile, the tortoise is one-eighth of a mile ahead, and the judge scores again. And so on. The tortoise at every score is to be found just half as far ahead as he was at the preceding score. But Achilles has not overtaken him.

And why?

Because Achilles has not run long enough. That is the whole mystery. And by the implied terms of the race, implied in the method or rule of scoring arbitrarily imposed, he will not be allowed to run long enough to cover the original and the acquired distance between him and his competitor. He is scored against first when he has run one mile in one-half an hour; next, when he has run a half-mile in a quarter of an hour; then when he has run a quarter-mile in one eighth of an hour, and then when he has run an eighth of a mile in one-sixteenth of an hour; and so on. It is evident that Achilles is beaten. He is at length reduced to gaining an infinitesimal space in an infinitesimal time—which words, we may say, are an effort to express the inexpressible—but he is never permitted to run two miles or to stay an hour on the track.

For the minute distances added diminish by this law that they must always leave half the distance undone. The sum of such distances always approach to unity, but never can reach it. Achilles was beaten at the first score, just as truly as at the last. He was beaten by the terms of the race in plain figures before he started. *Therefore, Zeno was right.*

But now, let us permit Achilles and the tortoise to run for an hour—for just one plain sixty minutes—and then see what will happen. Inasmuch as Achilles runs two miles in that hour, and the tortoise one mile; and inasmuch as the tortoise had one mile the start of Achilles, it is obvious that at the exact end of one hour Achilles will have run two miles, and the tortoise one mile, which added to his mile of advantage, will give him two miles also. Therefore he and Achilles will be exactly abreast. Achilles will have overtaken the tortoise. *And Zeno was wrong.*

If Zeno meant to affirm that no one body in motion could ever overtake another body moving at a slower rate, but having a definite "start" (however small), both bodies to move along the same path, no one need hesitate to contradict him flatly. Only by "keeping the score" according to the method above outlined can such an affirmation be sustained.

If we allow the tortoise only an infinitesimal advantage, and allow Achilles to run a billion times as fast as the tortoise, still the latter will win. Forgetting the terms of the race, this looks like a proof that motion is impossible, even the smallest. But the fallacy is shown above.

It will also be clear from what has been said that the difficulty of the problem does not arise from any latent conflict in its terms between the potential and the actual, or between the finite and the infinite; or between the physical and the metaphysical. The terms involved are all finite and actual and physical. It is a plain question of division and addition. The trick is so to divide the number one into a diminishing and regular series of factors that the whole number shall never be reached by adding these factors together again. This is done at once by requiring that the series shall be $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, and so on—not *ad infinitum*, for no infinitum can be reached in this way, but so long as you can keep it up without exhaustion. In fact the condition is made at the outset, in set terms, that the number shall *not* be exhausted at any term of the process, but that some definite fraction of the remainder shall always be left. Zeno's pregnant apothegm, that to say a thing once is to say it forever, is numerically exhibited in such a series. To fail in the first division, say from the half to the quarter, is to fail in the next and for ever.

On no other conditions is it true that Achilles cannot overtake the tortoise.

He is tricked out of the *time* necessary to accomplish the feat, and that is all the mystery there is in it.

We may be permitted to vary the puzzle. A grocer says to his man, "John empty that barrel of sugar," John dumps it forthwith, and the command is fulfilled. But now if the grocer had said, "John, empty that barrel by first throwing out one half, then half of the remaining half, then half of the remainder again, and always only half of the remainder; it is clear that John will *never* empty the barrel. The imposed conditions render the feat impossible.

Now this does not prove the impossibility of emptying barrels; neither does Zeno's case prove either the possibility or the impossibility of motion. This is our third proposition.

There is a parallel paradox in the saying that since a body cannot move where it is, and cannot move where it is not, therefore it cannot move at all. The fallacy here is grounded in an oversight. Everybody knows that the premises are somehow true, and equally well that the conclusion is false. But everybody does not notice that a body in motion does not move either where it is or where it is not, but that it is in a state of change, the change consisting in the very act of going *from* where it is, and *to* where it is not. In other words, motion is not rest. It is only during rest that a body exists where it is. Motion means the cessation of this rest.

But this is a digression. The question remains, Has Zeno proved the possibility of motion, or its impossibility, by his paradox, or by any other process of thinking? He has not. He has assumed motion and all of its implications—velocity, direction, time, and space—and has shown us that a man running two miles an hour cannot make two miles in less than an hour. And that is all that the example proves.

But now, is there no significance whatever in the argument? Is there no meaning in the problem—no use in the solution of it—no ground from which it legitimately arises?

The race between Achilles and the tortoise may indeed be no more than a skilfully devised 13–14–15 puzzle in value.

But the problem involved, Is MOTION POSSIBLE? has a very substantial ground, deep meaning, and very serious consequences.

So far as we know, Zeno himself did not apprehend clearly, nor did any of the Greek philosophers, the true ground of the question. But he felt the pressure of the problem, nevertheless, when confronted by some of the implications of motion.

So long as those philosophers were content to accept naïvely the physical conception of space and time, or a conception grounded in plain physics, so long all was harmony in their thought-world. But when the effort was made to determine more exactly and clearly the nature of space and time, and when some of the metaphysical aspects thereof intruded themselves, the skies grew cloudy. It was the undeveloped metaphysics of space and time that made the Greek conception of them unsatisfactory, unclear, and troubled. This throws doubt on all our conceptions of motion, as that which can only occur through space and during time. What Zeno and his immediate successors thought about these matters, we have no means of knowing; but that the very doubt of the possibility of either motion or change of any kind could possibly arise in the Greek mind, reveals the presence of a metaphysical upheaval more or less complete. Otherwise no such doubt is possible.

How did such a question arise, and what is the essence of it?

It arises from the necessity imposed upon thought of thinking itself and its objects over and over again, always with the intent of attaining to clearer and completer knowledge. The process invariably uncovers defects in primary conceptions, and introduces a conflict between these and their inevitable successors. Thus arises the question: Now what is the essence of it?

The essence of it is, What is the true nature of space and time?

Is space a void, a mere emptiness, a nothing?

Is it a material substance?

Is it, our own capacity of thinking, an outer void?

Many more such questions can be asked, but these must suffice for the present purpose.

But it is manifest that if we answer these questions in one way, physical motion, as ordinarily conceived, is the real truth of nature. While if we answer them in another way, such conception is founded on an illusion, not unlike that which leads us to say that the sun rises and sets, when we know that it does not; and the truth of nature is all changed in a twinkling. Nature *appears* indeed to our senses as a multitude of objects moving through spaces and during times.

But this is only phenomenon—appearing. To thought it cannot be so in very truth. To thought no such movement is possible—at least not without an interpretation. This may indeed be such a world as it appears to be on first impression, a world of material objects in motion through space and during time. But the question is possible, May it not be a power, no less genuine and real, such that it appears through our sense-consciousness so to move? In this latter case, crude physical motion becomes a mere phenomenon, and if taken for the genuine truth, an illusion. Motion in this case is not physical, but metaphysical. The consequences are of the gravest kind. Zeno's problem is full of meaning.

SCIENCE A RELIGIOUS REVELATION.

Richard T. Ely, known as the author of *Socialism and Social Reform*, begins an article on the "Fundamental Beliefs in His Social Philosophy," published in the present number of *The Forum* with these paragraphs:

"A scientific person dislikes creeds. Science is not religious revelation but a progressive unfolding of truth. When I am asked, 'What is your social creed?' I naturally reply, 'I have no creed.' When the editor of *The Forum* asks me for an article on my creed, I am obliged to answer that I have none. What have I to do with a creed in economics or, more strictly speaking, general sociology? For it is in reality a sociological creed that is wanted.

"Yet more mature thought reveals to the man of science that he may after all go too far in his opposition to a statement of his opinions. As the result of his studies, and, in a case like the present, also of his experiences in life, he may have reached certain conclusions of value to others. There may be no impropriety in a statement of these conclusions provided it is understood that he reserves the right to change his opinions if longer investigation and riper experience reveal mistakes."

The adherents of all religions, without exception, believe that their confession of faith is the best formulation of truth obtainable; and we may safely define the religion of a man as his aspiration of living in agreement with his conception of truth. The idea of a creed which by its devotees is not identified with the truth is an absurdity. If, then, science *is* as Professor Ely says, "a progressive unfolding of truth," science necessarily is a religious revelation, and if there are people who deny the religious character of science, they can do it solely on the ground that science is not supposed to be capable of unfolding the truth and that truth must be attained through other channels, such as intuition, ecstatic visions, or extra and contra-natural revelations.

Professor Ely says: "A scientific person dislikes creeds." Good. But is there any religious or irreligious person who regards the acceptance of a creed as a religion? If there are they are wrong. There are people who think, that because most religions have creeds, all religions must have creeds. But obviously, the religion of Buddha in its purest form has no creed. Buddha in his dying hour enjoins his disciples not to follow the authority of any one, not even of himself, the master, but to exert themselves to find the truth by their own experience. Can we call the doctrines of Buddha a creed? But even if all the religions in existence were creeds, creed cannot be considered an essential element in religion. Creeds, ceremonies, and modes of worship are the husks only of religion, the kernel which they cover is man's hunger after truth and righteousness. If there are no creedless religions, the duty devolves upon us to create one.

All truth is sacred. He who trusts in truth and regards truth as the saviour that alone can afford enduring salvation; he who endeavors to find the truth with the best, most rigorous and painstaking means at his disposal—and the best means for accuracy and reliability that are at the disposal of mankind are commonly comprehended under the name of science—he who is fearless in accepting the truth and not ashamed of changing his opinion whenever weighty arguments convince him of error; he who leads a life of truth and remains faithful to the noblest of his convictions, is (whether he adopts the name or not) an adherent of the Religion of Science.

Science, i. e., the mere search for knowledge and the knowledge acquired, is not as yet religion, but being a gradual unfoldment of truth (unfoldment is but another word for revelation), science can—or, better, must—enter into our religious conviction as one of its most important elements. In fact, all religions are constantly being purified by the wholesome influence of science. Science must be the regulator of those of our ideas and principles—or maxims—which ultimately determine all our actions. It must be recognised as the basis of the moral development of our lives—in a word, science must become a religious factor.

He who understands the signs of the times can see the straws in the wind which indicate the direction of religious progress. We can, visibly to our eyes and audibly to our ears, observe in all our churches, and especially in the most orthodox ones, a broadening of the spirit of toleration and a mental growth affording more breadth and a greater depth to our religious sympathies. The old prejudices are giving way to a better comprehension; the narrowest minds are struggling to free themselves from their sectarianism, and a latitudinarian conception, far from being repudiated or denounced, as formerly it was, has become the common ideal of all denominations.

Having abandoned the old metaphysical speculations, and having discovered the hollowness of ontological systems, many scientists are inclined to surrender philosophy as a hopeless task and a futile chase after an *ignis fatuus*. In the same way, having come to the conclusion that creeds are unverifiable and even irrational assumptions, many honest searchers for truth reject religion as a vagary of the human mind. But both are mistaken. The vagaries of the past render neither philosophy nor religion impracticable. What we need in philosophy is a philosophy of science. What we need in religion is a religion of science.

The philosophy of science abstains from building ontological air-castles, but attempts to construct a world-conception on the basis of the truths established by science.[1] And the religion of science proposes to regard science not only as *a* but as *the* religious revelation. Science—I mean genuine science and not the vagaries of sundry scientists—is holy, and the voice of science is divine. If God ever spoke to man, science is the fiery bush; and if there is any light by which man can hope to illumine his path so as to make firm steps, it is the light of science.

Let us, therefore, make religion scientific and science religious. Let us, on the one hand, imbue religion with the spirit of science, with its rigorous criticism, strict exactness, and stern devotion to truth; and on the other hand, let us open our eyes to the moral and religious importance of the results of scientific inquiry. The ultimate aim of science is to reveal to man the religion of truth.

Rituals and symbols, nay, the very names of religious denominations, may vary according to historical tradition, taste, and individual opinion, but the essence of religion can only be one, and must remain one and the same among all nations, in all climes, and under all conditions. The sooner mankind recognises what this essence of religion is, the better it will be for human welfare, progress, and international relations. The realisation of the religious ideal alone will bring glory to God in the highest and peace on earth towards the men of good-will.

[1] For an exposition of the details of this view, especially as to how the philosophy of science has to derive the principles of scientific inquiry from the facts of experience, without forgetting the difference between mental operations and sense-impressions, see my *Primer of Philosophy*.

THE TRYST.

BY CHARLES ALVA LANE.

Of old time Grief met Joy beside the sea,
  Where day ebbed off in sunset's foamy light:
  Joy westward wending, fleeing from the night;
Grief forward faring, wan and wearily,
Toward the glooming east of memory.
  "O, doleful sister!" quoth the radiant sprite,
  "Are we no more to meet in dark or bright,
While all the seasons live that are to be?"

"Yea, where the Poet dreams be place of tryst
  To mix our loves whom fate doth part," she said;
"So shall my tears, by thy effulgence kissed,
  Be kindled into rainbows 'round his head,
Till through the song ambiguous beauty wiles
To sighing ecstasies and yearning smiles."

NOTES.

The famous passage quoted at the end of the editorial article runs, in the King James translation of the Bible: "Glory to God in the highest, and on earth peace, good-will toward men." This verson is based upon the following reading:

"Δόξα ἐν ὑψίστοις θεῷ καὶ ἐπὶ γῆς εἰρήνη, ἐν ἀνθρώποις εὐδοκία."

Another version, however, which omits the comma and reads εὐδοκίας is among scholars considered as more probably correct and has been adopted in the Cambridge edition of the Greek text (published by Macmillan & Co.) so that the latter part of the sentence would have to be translated "And peace upon earth towards the men of good-will"—or literally "in the men of good-will."

THE OPEN COURT

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