that it is impossible to say definitely whether it has been observed or not. But it is not so well known that the assumption that would lead to no spectral shift leads to the result that the wave-length on emission of light from a particular type of atom is a function of position; thus the abandonment of *ds* as the fundamental measured quantity would not make it possible to carry both length and time standards about unaltered. Probably the difficulties arising from the hypothesis that *ds* does not play two parts are so great as to render it quite unplausible.

The Metaphysical Aspects of Relativity.

By PROF. H. WILDON CARR.

THERE is a possible misconception in the application of the term "metaphysical" to the new principle of relativity which it is advisable to clear up In the great era of the triumphant advance of the positive sciences, which began about the end of the first third of the nineteenth century, metaphysics was decried as the main obstacle to scientific progress. Following the lead of Auguste Comte, the workers in the sciences held it up to scorn as obscurantism. The derision and reproach which were then poured on it have clung to it ever since. There are many to-day who acknowledge, indeed, that metaphysics must be assigned a place in the hierarchy of the sciences, but interpret the Aristotelian definition, "that which follows or comes after physics," as indicating a dark realm of the yet unknown, or even of the unknowable, which surrounds the clear zone of positive knowledge, into which we may peer, but will discern nothing. The objects of metaphysics—the soul, the cosmos, the deity—are in this view vain imaginings, not objects of which there can be knowledge in the scientific meaning—that is, objects amenable to the experimental method. Such a view simply ignores the scientific tradition. Modern science is the result of the formulation and adoption of the experimental method, but the experimental method is not self-evident or inherently rational; it depends on a metaphysical concept, and its rationality can be established only by metaphysical principles. To contrast, then, the experimental method with the principles on which it depends, to describe one as the realm of science and the other as the realm of ignorance or unknowability, is from any philosophic point of view stultifying, and, in the literal sense, absurd.

What has made it possible to consider metaphysics as an unreal science, or as a realm of unreal fancy, is the peculiar position in regard to the natural sciences in which the purely mathematical sciences stand. Mathematics does not use the experimental method, and in the hierarchy of the sciences mathematics seems sufficient of itself for the foundation and support of the whole superstructure. But mathematics is only an abstract science of quantity; its concepts lack the one essential character which experimental science calls for—concreteness—and this metaphysics alone can supply.

The modern era of philosophy from Descartes onwards has been dominated by the insistence of the scientific problem—that is, the problem of the ultimate nature of the reality we study in physical science by the experimental method. This interest in the nature of scientific reality replaces the main interest of the philosophy of the mediæval period, which was concerned with the origin and destiny of the human soul, and, more generally, with the relation of man to God. If modern philosophy may be said to join hands with the ancient philosophy of Greece, it is not in the identity of its interest; for, though the Greeks were mathematicians, they had no conception of the experimental method as we practise it, and it is even doubtful if it could have been made to appeal to them on the ground of rationality.

The principle of relativity is the direct outcome of the application of the experimental method, and the full force of its appeal is based on our absolute confidence in the metaphysical concept of reality which is the ground and reason of that method. The experimental method has taken possession of the modern mind, and it assumes for us something like the unmodifiable character of an instinct. If experiment proves a certain velocity to be constant under conditions which require us to predict its variation; if experiment shows the movement of a source of light to be without the expected effect on the velocity of propagation—well, it is our concept of the nature of reality which must adapt itself to the experiment. The prediction is based on the concept that space and time provide an absolute system of reference; the null result of the experiment negatives that concept, and henceforth space and time are "shadows"; they must vary, because under varying conditions velocity is constant.

Those who affirm that the principle of relativity is purely mathematical, and not metaphysical, and, therefore, resent the intrusion of metaphysics into the discussion of its equations, conceive the principle to be purely methodological, to be concerned only with abstract quantitative measurement, and merely to substitute a very complex and difficult set of equation-formulæ for a discarded simpler one, in the interest of greater precision and accuracy alone. Those who take this view seem to me to misapprehend the significance of the principle. It is to be understood only when taken in its historical connection with the metaphysical constructions of the great philosophers.

Since Descartes, the speculations of philosophy have centred round the concepts of substance and

cause, and the principle of relativity in its two phases, special relativity (the restricted theory) and general relativity, is essentially concerned with these two concepts. The first phase, in its negativity towards the æther hypothesis, is a reform of the notion of substance; and the second, in its rejection of influence and its substitution of equivalence for attraction in a new theory of gravitation, is a reform of the notion of cause.

Two opposing principles in regard to both these concepts—substance and cause—have been struggling to establish themselves throughout the modern period—one taking as its type the objective or passive aspect presented by the world to the mind of the observer, the other taking as its type the subjective activity of the mind itself in perceiving, imagining, understanding, willing, and acting. The first type we have in Descartes' concept of material substance as consisting in extension alone, and in his concept of cause as the mechanical action and interaction of a definite quantity of movement imparted to the extended substance—the concept of a mechanism which embraces the whole universe, organised and unorganised, exclusive only of the other substance, thought or thinking, present in human beings alone. Later we have the same type in the more familiar concepts of Newton—absolute time and absolute space. "Absolute time, in itself, and from its own nature, flows equally, without relation to anything external." "Absolute space, in its own nature, without relation to anything external, remains always similar and unmovable." The other type of concept we have in Leibniz's monadology. Substance is not passive, but active; cause is not movement, but force. What does nothing is nothing. Time and space are *ordines rerum non res*. Things are centres of active force.

It is with these concepts of substance and cause that the principle of relativity is primarily and mainly concerned, and these concepts are metaphysical constructions. Experimental facts have called for the formulation of the principle, but those facts themselves have slight importance in the practical sphere; it is their theoretical consequences which are far-reaching and revolutionary. They are facts which prove to be decisive in regard to metaphysical problems. The experiments are concerned with such infinitesimals as forty-two seconds in relation to a century, or a variability of $2\frac{3}{4}$ in. in the diameter of the earth. It is not the facts themselves, therefore, that are important, but their significance. According to the view which I have put forward in my book, "The General Principle of Relativity in its Philosophical and Historical Aspect" (Macmillan and Co.), the principle of relativity definitely decides for us that our universe is monadic, and that our science does not derive its validity from a reality independent of the monads, but from a power inherent in the monads to co-ordinate ever-varying points of view. By monads I mean minds, but minds conceived as metaphysical reals.

The point of supreme and central importance in the principle of relativity in its bearing on metaphysics is its negative attitude to the concept of absolute space and absolute time continua. The principle accepts the null result of the experiments as decisive in regard to the non-reality in the physical sense of such continua, and it refuses to recognise any necessity to construct *ad hoc* a hypothetical absolute space-time system. On the other hand, it claims to provide a formula which expresses the identity of an event for two observers in different systems who pronounce it to be one and the same, without the necessity of affirming an absolute order independent of their systems of reference.

Why does this seem paradoxical and in contradiction to our ordinary experience? Because our experience consists in the observation of events which we do not cause; which we refer to in our intercourse with our fellows as common to them and to us; and to which throughout life we, automatically or consciously, react. We argue by what appears to us the most perfectly natural reasoning that the identity of an event for two different observers implies an absolute order by reference to which alone differences of observation can be reconciled. This absolute order, we think, can be nothing else but the determination of every event in regard to every other event in an absolute coexistence in space and in an absolute succession in time. We conceive, therefore, an absolute space-time order, and suppose our private space-time systems are related to it. Such is the course of reasoning which appears natural, and such is the logical necessity from which it appears impossible to escape. Metaphysicians have long disputed it, but their arguments have been generally set aside as logomachies. Experiment has now falsified it.

What sort of thing, then, is the relativist universe? Substance and cause—that is, the principle of unity and the principle of uniformity—are definitely transferred from the object to the subject of experience. I do not mean that object and subject are dissociated; I mean that substance and cause are declared to be functions of the essential activity, and not of the passivity of experience. Thus the universe depends on the subject of experience, not, indeed, in the old and often derided sense in which the philosopher is caricatured as evolving an external world out of his own inner consciousness, as the spider spins its web, but in the sense that the universe is the co-ordination which the observer effects. The universe has four dimensions—the three dimensions of space, and the one dimension of time. The principle of co-ordination is that every observer uses his own axes of dimension, taking his system of reference as fixed in relation to all systems which for him are moving, and he is able to do so because his four axes are variable, and every change in his own system of reference, relatively to other systems, is compensated by a variation in his axes of co-ordination which preserves the ratio constant.

The universe, then, which the principle of rela-

tivity affirms is a universe in which there is no absolute space-time order; in which every event is exhausted in the contradictory descriptions of observers in different systems of reference; in which systems of reference are ultimate without being absolute, and relative without being externally conditioned; in which every system is self-sufficing and contains its own norm, a norm which remains constant by changing as the system changes. In such a universe, are mathematics and physical science possible? The relativist claims that they are capable of infinitely greater precision and consistency than they could ever attain while obstructed by the old concept.

Bibliography of Relativity.

A BIBLIOGRAPHY of all books, pamphlets, papers, articles, and other publications on the subject of relativity has been prepared by Dr. H. Forster Morley, director of the International Catalogue of Scientific Literature. The list includes nearly 650 titles, arranged in chronological order from 1886 to the end of last year. It would occupy about thirty columns of NATURE, and, much as we should like to print it in full, limitations of space render this impossible. We have, therefore, extracted from Dr. Morley's bibliography the titles of published books and pamphlets upon relativity and related subjects, and also the references to articles, notes, or other contributions which have appeared in the pages of NATURE. The complete bibliography is so valuable that we trust it will be published in full either by a scientific society or in a leading work on relativity. Dr. R. W. Lawson has kindly added the titles of a number of German works.

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