

# Philosophy for Science Students

By John J. FitzGerald

EINSTEIN'S resolution of the apparent incompatibility between the Newtonian principle of relativity and the law of the constancy of the velocity of light *in vacuo* by a reflective analysis of the physical conceptions of time and space disclosed, in theoretical physics, the unsuspected operation of an epistemological factor which had already been discerned in experimental physics by Duhem, Poincaré, and others. The analysis and interpretation of this factor have originated a variety of philosophies of science which are relevant here only as they offer unmistakable witness to the bearing of philosophy and its characteristic procedures upon physical science; a bearing in the ignorance of which one might achieve distinction in science without, however, understanding one's claim to distinction. On the assumption that this bearing presents the only available, solid, practical ground upon which scientist and philosopher can meet, each without benefit of the highly specialized and sustained training demanded for competence in these areas today, we, at Notre Dame, are in the process of constructing and presenting a course in philosophy for majors in physics and mathematics. The purpose of this paper is to sketch, for any helpful comment which it might evoke, the origins, content, spirit, and aims of this course.

Two factors, one local and circumstantial, the other general and fundamental, contributed to the formulation of the purpose of the course. The general and fundamental factor was the epistemological dimension of modern physics suggested above. The extrapolation of the successful rationale of physics and mathematics to other realms of systematic inquiry, in particular to philosophy and theology, had inclined some of the brighter science majors to an epistemological relativism and a metaphysical skepticism. Their implicit reasoning was simple enough: in mathematics and physics, explanation is a function of definition and assumption of which the only requirement was inherent consistency. In their view, the validity of this mode of explanation was confirmed extrinsically in the impressive control over nature achieved in the application of its results in the applied sciences. This, the local and circumstantial factor, moved the departments of physics and mathematics to cooperate with representatives of the phi-

losophy department in the construction of a course in philosophy for science majors which would open their minds not so much to the inexhaustible fecundity of the mathematical-physical method and mode of analyzing and explaining the details of observable phenomena (to which their minds were already widely opened) as to the inner limitations to which the very excellence of this epistemological type confines it. Hitherto, these science majors had taken traditional courses in logic, introduction to philosophy, and moral philosophy along with the students in the liberal arts college. Their estimate of these courses was not particularly flattering; in their view, the speculative or reflective character of these philosophical disciplines was the inevitable consequence of the philosophers' failure to assimilate the first practical lesson of modern science: the unambiguous selection and description of the data at the level of experience, and the construction of a precise symbolism and coherent operations at the level of explanation. Accordingly, they looked upon speculative sciences in general and philosophy in particular as any set of loosely related propositions exhibiting in respect to their subject matter a verisimilitude not susceptible of verification. With the sincerity of this impression, there could of course be no dispute; its accuracy, however, was at least open to discussion. Under these circumstances, the over-all problem of our introductory course in philosophy for science students was apparent: the relation, if any, between the philosophical and non-philosophical sciences of the space-time world given initially and immediately in our external sense experience. Because it is factual, the historical discontinuity of these two ways of accounting for the events of nature and their apparent order suggested itself as an appropriate context in which to set forth the over-all problem.

PRIOR to Galileo and his contemporaries of the 16th and 17th centuries (except in the limited fields of astronomy, rudimentary optics, and acoustics), man's so-called scientific knowledge of nature was epitomized in the physics of Aristotle universally viewed as the philosophy or science of nature. With the success of Galileo's new method and the whole history of experimental science since in demonstrable contradiction to some of the results of the old Aristotelian physics, the designation of our sciences of nature as *the* or even a natural philosophy has all but disappeared. Quite natu-

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rally, the question arises whether, beyond this historical order of succession, there could be any relation between these knowledges of a same universe which transcends origin in time and if so, what precisely is it? The fact that, instead of disappearing, philosophy has continued to engage competent minds deserves some consideration. Stated in this way, the problem tends to stand forth in its properly epistemological character while at the same time engaging directly the acquired insights and most refined experience-to-date of the science student.

Thus, for psychological as well as pedagogical reasons, we took for the point of departure of our course the historically factual discontinuity between what, for convenience, we called the philosophical and nonphilosophical sciences of nature. In this setting of the problem, two apparent views of their relation suggest themselves from the outset: either the pre-Renaissance natural philosophies were primitive adumbrations of that single scientific type of which Newtonian and modern physics are the intermediate and presently advanced expressions, or, despite some overlapping and confusion in their historical genesis, these are specifically different epistemological types and, as such, irreducible but complementary to the extent that no relatively complete scientific understanding of the observable universe and ourselves, as parts of it, is possible without both.

Such a setting of the problem also suggested the division and the order of the parts in its treatment. It seemed quite clear to all that any effective handling of the relation in question demanded a sufficient understanding of the related terms themselves. But how, in all honesty, could one aspire to acquire in part of a single semester a sufficient minimal understanding of either term, not to mention both? To be sure, if one construed a sufficient minimal understanding to be a professional or expert competence in either, the problem could not significantly be formulated to say nothing of being resolved. Presumably then the sufficient knowledge in question was of another order than the endlessly expanding knowledge of the expert acquired through years of training and experience in either field. To suggest this difference, we distinguished between a critical knowledge of science or philosophy and a scientific or philosophical knowledge of things. Without some scientific or philosophical knowledge of things, it was clear that a critical knowledge of either science or philosophy would be impossible. It was assumed, in the beginning, that the necessary minimum knowledge of each could be acquired within the time limits under sustained and cooperative competent direction.

The distinction between a critical knowledge of a science and an expert knowledge of a science presented a two-fold advantage. First, it tended from the beginning to focus the students' attention upon the reflective or epistemological character of the inquiry, that is, upon the fact that they were not investigating things directly in the physical or philosophical manner but were rather studying reflectively the sciences which result from

such direct investigation of things in order to discern the typically unchanging traits and values of such sciences. Secondly, it suggested the materials and the order of their treatment in the first part of the course which was concerned with the structure and limits of the nonphilosophical or physical sciences of nature.

To acquire the minimum knowledge of physical science required for our purposes, we followed the historical-logical development of the atomic-molecular theory from the Dalton atom to the first formulations of the Bohr hydrogen atom as a prototype of the development of every rigorously scientific explanation. Though akin to Conant's method of case histories, used in his Terry Lectures at Yale and later in his popular book *Science and Common Sense*, this procedure is less historical and descriptive, centering as it does on the growth of science in a continuous section of its history rather than on typical structural items as exemplified in historically unrelated or remotely related instances. In this section of our course, our method, in the very nature of the case, was largely expository and historical. Though the data and formal concepts accumulated were largely familiar to the science students, the different and successive intelligible content, as it emerged in their historical development, was not. Gradually, it became clearer for some that though its history is without significance in learning science (being, as it were, "its dead past") it is of the utmost importance in understanding science as a specific epistemological type. In the progress from the readily imaginable and highly qualitative chemical atom constructed by Dalton to account for or explain the observed regularities of the weight relations in simple chemical reactions, through the less imaginable and entirely quantitative nuclear atom of Rutherford to account for X-ray and alpha particle scattering, to the unimaginable Bohr hydrogen atom to account for various radiational phenomena, the student gradually turned his attention from the singularities of these successive historical conceptions to the significance of their succession and the recurrence in each of certain fixed epistemological patterns transcending their objective content. Thus, from an initial preoccupation with particular experimental data, laws, and theories, the student's gaze passed quite naturally to a curiosity about the value and limits of the knowledge resulting from such interrelated items. At this point, our distinction between a critical understanding of science and a scientific understanding of things became something more than verbal. Some were quite ready to concede the possibility of having a physical understanding of experimentally observed events and processes without understanding physics while, at the same time, recognizing the impossibility of understanding physics without a sufficient physical understanding of things. Finally, the awareness began to dawn that the effort required for an understanding of science as such is of quite another order from that required for a scientific understanding of natural phenomena. Accordingly, it demands essentially different analytical and explanatory procedures.

HAVING exposed the limits of our competence, challenged all along the way by the students' own competence, the fundamental steps in the historical-logical development of as much of the atomic molecular theory as sufficed for the material requirements of a critical understanding of science, we extracted the recurrent epistemological elements in each phase of the development for separate analysis in the second and formally epistemological phase of the course. In this phase, demanding as it does an intimate, personal reflection on the genesis and precise signification of a physical datum as such, a physical law as such, and a physical theory as such, the student's mind became more closely engaged with the problem. In this reflective light, a physical datum appeared to be a datum of experience so isolated with instruments that the conditions of its behavior could be controlled and its characteristics described unambiguously in terms of the recoverable readings of measuring operations. Here we considered the distinction and irreversible relation between what might be called the brute fact of pre-scientific experiences, such as the falling of a body, and an experimental fact, the stuff of scientific experience, such as the constant accelerated velocity with which it falls. Prior to and presupposed by scientific experience stands given a same complex, throbbing universe of spontaneous experience, the space-time world of things and events which invades our sense consciousness as soon as it awakens. From the bewildering richness and inexhaustible mystery of this given world, science separates its original data with instruments which not only reduce to a controllable minimum the subjective factors of our qualitatively differentiated sensations but, likewise, expand their range of observation to otherwise inaccessible phenomena. More significantly for the objectivity of science, the phenomena so isolated are characterized and classified in terms of the concrete readings of the instruments and can accordingly be verified under the same conditions by any competent observer. In this way such sensible qualities of spontaneous experience as heat, light, and sound can be identified quantitatively and communicated in unequivocal, conventional symbols.

The phenomena, identified and classified in this way, are found to exhibit relations which can accordingly be expressed in equations susceptible to mathematical manipulation and interpretation. Uncorrelated or random data appeared unintelligible unless in the aggregate they exhibit at least a probable pattern of behavior. The statement in appropriate conventional symbols of such observed relations between distinct data, exemplified in the classical weight laws of chemical reactions or Ohm's law for an electric circuit, appeared to constitute an empirical as opposed to a theoretical-empirical law for science. Our reflective analysis disclosed that an empirical law in science simply stated a factual relation without involving any reason or cause for the relation. The fact that, under usual conditions, any increase in the temperature of a relatively rigid bar will invariably be accompanied by an increase in its linear

dimensions may be simply but equivocally expressed in the verbal formula "heat expands metals". This formula appeared to be equivocal to the extent that it conveyed the sense that heat is the cause of the expansion of the metal. At the empirical level, scientific laws, as exemplified by the typical instances considered in the historical-logical section of our course, appeared to be without such causal signification.

Not until such laws have been synthesized in more general physical relations (whose terms are ideal, as unobservable, rather than real as observable) from which they can be deduced, do they acquire a causal import. Thus, once the heat intensity of a system is explained in terms of the kinetic theory or the average motion of the molecules of the system, a cause for both the heat and the linear expansion of the system emerges. But here one passes from one irreducible level of science, the experimental, to another related but irreducible level of science, the theoretical, at which the experimental data, sets of facts, and the observed relations between them, acquire a meaning and significance conferred by the constructive or creative energies of the theorist's own mind rather than imposed necessarily by the data themselves. To be sure such theoretical constructions are not entirely arbitrary, controlled, as they are, on the one hand by the data to be explained, and on the other hand by the rules of the appropriate mathematical interpretation. Nonetheless they remain creations of the scientific intelligence to the extent that they propose what Bridgman has aptly called the plausible as opposed to the real causes of the experimental systems studied. In the required reflective light, and, as exemplified in the successive theoretical moments of our historical model, the function of a theory as such in science appeared to be comparable in relation to the empirical laws to the function of these laws in relation to experimental data. But where the relation expressed by the law is real as observed, that expressed by the theory is ideal or postulated as unobserved and, in principle, unobservable. In our model, two types of theory appeared: the one, mechanical and imaginable, the other, mathematical and unimaginable. On analysis, the mechanical one, as exemplified in the Dalton atom, appeared to be a special case of the more general and unimaginable mathematical one, as exemplified in the Bohr atom.

INEVITABLY this analysis of the theoretical structure of physical science as exhibited in our sample, so to speak, of its development in time, confronted us with the vexed issue of its truth value or relation to the initially given universe from which, at the experimental level, science extracts its characteristically quantitative data. The inherent relativity of these data as terms of experimental operations, products of the technological ingenuity of the scientist and susceptible, accordingly, to endless development, appears to introduce into this kind of science at the most fundamental level a factor of contingency precluding any but an approximate and relative truth to its utterances. From the data, this in-

herent relativity spreads through the laws, which correlate the data, to the theories, which correlate the laws. Those scientists who have discerned and considered this essential relativity of their data have interpreted its epistemological effects in quite different ways. For Eddington, it excluded as a meaningless issue every question of the relation between science and the existential real. Accordingly, he defined the physical universe as the theme of physical science, a theme which remains quite indifferent in its objective import to the irresolvable issue as to whether such a universe has any existence outside of the scientists' portrait of it. For Conant, the existentiality of both the observer and the observed appears to be a necessary assumption drawn from prescientific common sense. For Einstein, science is nothing unless it is of a really existent universe as the ultimate term in which it is verified and its truth confirmed.

Confronted thus with the internal evidences of physical science itself and this diverse external witness to its truth value or relation to the existential real by some of its competent exponents, we concluded to a tentative position, the adequacy or inadequacy of which would be tested by the students' own developing experience as they advanced in their scientific studies. In substance, our position consisted in acknowledging, on the one hand, the inescapable relativity of the initial physical data as terms of necessarily approximative instruments and operations. This acknowledgment, however, in no wise diminishes the recognition, on the other hand, of a given universe of brute facts, evident in their existence, which the instrumental operations render scientifically intelligible. In the light of these evidences, the original physical data, the collection, correlation, and explanation of which constitutes the complete function of physical science, must be regarded as constituted inseparably of an existentially "given" in its interaction with an imposed artifact, the instrument of measure. In this interpretation, the sense of Eddington's evaluation becomes clear and valid to the extent that to ask what the thing measured is in itself apart from its measures is without physical meaning. But this in no wise means that it has no meaning in itself as prior to and demanded in its existence by physical science, though this meaning be, as suggested by the interpretations of Conant and Einstein, unformulable in specifically physical terms.

Respecting both these original evidences, the existentiality of the brute fact and the relativity of the measured fact, we concluded that theory in science can be said to be proximately true to the extent that its consequences are, in whole or in large part, experimentally verifiable. This view is compatible with the historically factual coexistence of theories which, in their assumptions, are mutually incompatible but, in their consequences, are experimentally verifiable. It also, in the spirit of Eddington, prescinds from any position in respect to the existential import of logically coherent and physically meaningful theoretical statements. To discern and respect the prior existentiality of the brute

fact as the necessary condition of the existence and hence knowability of the scientific fact, we stressed a more subtle and dynamic feature of science as manifested in the cumulative development of the atomic molecular theory as far as we were able to follow it. This feature may be called the intensive as contrasted to the extensive direction of scientific progress; a direction which, on reflective analysis, seems to find its ultimate but unattainable limit in the existential space-time real itself. To evaluate this feature of scientific knowledge, one is forced, in the nature of the case, to the history of science where, at each fundamentally significant advance, science is found to envelope wider sections of phenomena as it penetrates deeper into already known areas. The ideal term of this penetration in depth would appear to be the space-time real in itself which would account for the need, inherent alike in the scientist and his work, to return constantly to the given real to expand and control their achievements to date. Thus, as if to overcome the inescapable limits of its own self-imposed methodological limits, physical science strives to over-reach itself to penetrate the forbidden zone of the real in itself. By ignoring this tendency, no less real because of its subtlety, one would seem to run the risk of reducing physical science to its constructive dimension and thus extinguish its properly physical import by making it indistinguishable from mathematics. Whether the existential import of the initial datum and the final term of physical science be construed as an indispensable assumption of common sense, as Conant would have it, or the ultimate term towards which science advances, as Einstein would have it, the fact persists along with the impossibility of rendering it intelligible in formally physical terms.

**I**N the light of these suggestive insights, it was possible for us to turn to the consideration for itself of that intelligible factor in the space-time real to the necessity of which the physical sciences bear witness but to the analysis and explanation of which they are not equal. Here we confront the philosophic term of our basic science-philosophy relation. Here we have entered an area of problematic as old as Western Thought which can, accordingly, be broached significantly, though not equally fruitfully, through many different historical channels. For whatever the differences in their results and the reasons for these differences, the ultimate term of the quest remains the same in Socrates' search for the true definition of things, Aristotle's search for the first substance of things, Aquinas' search for the ultimate *raison d'être* of things, Descartes' search for the unchangeable rationale of things and Kant's search for the ground or source of a priori synthetic judgments. All of these, in so many different ways, contingent upon the intellectual climate of their moment in history, appear to be just so many responses of human intelligence to the challenge of the existential to which obliquely even the new sciences bear witness. From still another direction, because common sense, understood as the spontaneous certitudes of the prescientific as op-

posed to the reasoned certitudes of the scientific intelligence, likewise bears immediate witness to this factor in things, it is not surprising to find philosophy arising and developing in history centuries before the appearance of the nonphilosophical sciences. Though they fish in the same waters of reality, philosophy and science appear to do so at irreducibly different levels. The point of these rather sweeping generalities is simply that for students of science, there exists, within their science itself, an entry to the philosophical realm, an entry which not only respects the specific diversities of these knowledges but suggests their complementarity.

Thus, at the end of our epistemological analysis of physical science as such, we found, underlying and presupposed by the first datum of science, the experimental fact, an unmeasurable and unconstructed existential value to which natural intelligence or common sense also bears spontaneous witness; a value, in short, which imposes itself at every level of human knowledge but unfolds itself only at the philosophical level. Turning from the original datum of science to the scientific intelligence which separates or selects this datum, we found its curiosities, in a sense, over-reaching themselves and disclosing their own unchangeable limits. In its total curiosity, we found the human intelligence aspiring to nothing less than a possession, according to its own mode, of the whole of reality while confined, in its properly physical moment, to the measurable real which does not include itself.

What this real world which invades our consciousness through the external senses *might be* behind the rigorous facade of physical measurements, the physicist can and does propose in his theories. Such theoretical constructs are, we saw, by no means arbitrary fictions indifferent to the demands of the experimental evidences. Indeed such evidences, given rather than constructed, are, in the language of Eddington, the final court of appeal in determining the cogency of any physical utterance. But what this real world first grasped by the unaided senses *is* and cannot be in its ultimate determinants, the physicist as such cannot say. Thus, though we began in epistemology, and, in particular, in the epistemology of physical science as the prototype of all experimental science, our analysis ended in horizons beyond the limits of those disciplines in the elementary possession of which these particular students entered the course. Physical science appears to lead inevitably to these horizons when it becomes fully aware of its own invariable epistemological structure but it cannot enter into them with its essential procedures and operations. To the extent that the students' minds are opened, however dimly, to the irreducible heterogeneity of these two levels of understanding the real world in which he finds himself, to that extent, we think, he may be expected to escape that distorted total view which follows upon exclusive concentration in a single area of thought and, at the same time, lower the barrier to effective communication between scientist and philosopher which has arisen, it would seem, more as a consequence of undergeneralization than overspecialization.

## Books

**Readings in the Philosophy of Science.** Edited by Herbert Feigl and May Brodbeck. 811 pp. Appleton-Century-Crofts, Inc., New York, 1953. \$6.00. *Reviewed by P. Morrison, Cornell University.*

This is a careful compendium of essays within a more or less narrow interpretation of the scope of the philosophy of science. As Professor Brodbeck explains, the readings are restricted to analytic philosophy, to a study of meanings; the social study of science, its moral evaluation, no less than the speculative cosmologies and the natural ethical systems (like those of the *Naturphilosophen*), are all excluded. The logical analysis of science here collected leans perhaps a little too heavily on the works of logical positivists and their kin, from Mach and Poincaré to Carnap and Reichenbach.

An inventory of such a thick tome is unimaginative writing, but serviceable to the reader of a review: Here are about fifty papers, the shortest a few pages long, and the longest monographs of forty pages, arranged into a number of sections. The topics covered comprise the nature of scientific method, the logic of explanation in science and the nature of theory, the philosophy of mathematics, physical concepts, like the nature of space and time and of statistical and causal law, and finally, the philosophy of biological, psychological, and social sciences. There is an epilogue, touching on the sociology of science in a little piece by Professor Wigner looking forward from the Golden Age of today's naive individual effort to the necessity of group research in a future era. And a final page of Professor Einstein's seeks to found ethics upon the empirical values of the emotional experiences of men. (Were more men like Professor Einstein, his argument would be overwhelming.)

It is hard to let this large collection of deep and often bitterly-fought issues go past the reviewer without comment; it is no less hard to do any sort of justice to these fundamental questions in a few off-hand paragraphs. A few impressions may aid the prospective reader, or the busy physicist who wants only to notice the book. Two points were clear to the reviewer. First, much of the touchy and delicate argument of the book, though in the hands of many a wise professional philosopher, takes on a kind of triviality. Such an impression of emptiness comes across to a physicist reader, even to one predisposed to be sympathetic to the theory of theory. The ill-tempered Johnson was petty and naive enough to kick that stone, or the Latin writer to confound Achilles' tortoise by walking, but yet there is much sympathy for their simple-mindedness after an