PHYSICAL THEORY WITHOUT PRAGMATICAL IMPERATIVES

I. Introductory :

Modern physical theories of relativity and quantum mechanics are of deep philosophical interest in so far as they seem to have far-reaching methodological and extra-methodological consequences for the entire tradition of scientific enquiry. Some of the philosophically significant features of these theories involve a radical departure from : (1) the mathematical foundations of classical physics by introducing non-Euclidean geometry into the foundations of modern physics (general relativity theory);[1] (2) the absolutistic assumptions of classical physics by showing most of the fundamental physical concepts such as space and time to be of a relative character and statements concerning them to be of a definitional character (special relativity theory);[2] (3) the 'perceptibility' of classical physical theories by introducing essentially non-perceptible concepts of incomparable theoretical power (relativity theory and quantum theory); and (4) the entire deterministic structure of classical physics by rejecting strictly deterministic laws in favour of statistical ones in the micro-physical universe of the very small (quantum theory).[3]

Thus with the fundamental assumptions and essential structure of classical physics as their point of departure, these theories may be viewed from the methodological point of view of 'theoretical pluralism' as opposed to that of 'theoretical monism'.[4] Their revolutionary contributions to the growth of the *system* of scientific knowledge may indeed be seem as confirming the methodological value of theoretical pluralism for science. Points of methodological interest apart, the question which we wish to ask and consider in some detail in this paper may be formulated in very vague and general terms thus : What are the extra-methodological consequences, if any, of modern physical theory ? The problem, in a nutshell, is one of investigating the nature of such consequences which modern physical theory may be said to have for science on the one hand and philosophy on the other. The following section is devoted to a precise specification of the problem for purposes of present discussion.

II. The Problem :

One of the many interesting, and indeed revolutionary, features of modern physical theory is its non-perceptibility in a sense to be considered in the next section. This is best illustrated by the mathematical character of the relativity theory on the one hand and quantum theory on the other. In the discussions on the nature of these theories allusion to this particular feature is frequently made by describing the physical concepts and laws they employ as ones which, unlike their classical counterparts, cannot be visualized in terms of pictorial models based on more or less familiar objects of our experience. It is true that the character of these concepts/laws is instead described mathematically.[5] The immense theoretical advantages of this essentially non-classical mode of description violating some of the fundamental imperatives of classical physics is generally acknowledged by the physicists and philosophers of science alike.

Quite the opposite situation prevailed in classical physics where Newtonian mechanics dominated as 'the paradigm of a causal theory' and "'causal' and 'mechanical' became identified with 'picturable'".[6] Throughout its history, one notices in operation what may be called the perceptibility requirement as a general (pragmatical) imperative dictating the type of structure that a physical theory must possess. Frequent criticism of physical theories for their failure to possess the perceptibility feature was therefore characteristic of its methodology. For example, this is precisely how Maxwell's field equations for electrodynamical phenomena were criticized and sought to be supplemented by a mechanical model.[7]

In effect, the classical perceptibility requirement set definite limits to the scope and mode of physical description. A clear recognition of this fact became possible only in this century in the light of modern physical theories of relativity and quantum mechanics. Contemporary physicists seem to have lost no time in ruling out the possibility of a return to this mode of physical description.[8] Indeed there are reasons to believe that there is built in to the very foundations of modern physics a general requirement capable of replacing the classical requirement of perceptibility. One of the aims of the following discussion is to identify the distinct positive content of this alternative requirement. To begin with, we may simply call it the requirement of non-perceptibility, if only to emphasize its non-classical, revolutionary character.

The problem that emerges for discussion here centers around the question of the nature of these two opposite requirements and their place in the field of physical science. The point of view needed to make such a discussion seem worthwhile and interesting is provided by the modern semiotic analysis of language in the sense of R. Carnap and C. W. Morris.[9] Such a discussion becomes necessary also if the general philosophical implications of the requirements under consideration are to be seen clearly.

III. Perceptibility and the Pattern of Scientific Explanation :

All branches of empirical science aim at precise and systematic explanation of experimentally confirmed, more or less general relationships between properties of natural phenomena. It may be quite reasonable to require scientific explanation to follow some general objective, uniform pattern. Such a pattern is, e.g., readily available in physics in the history of atomic explanation, from Democritus to modern elementary particle theory.[10] The pattern here may be said invariably to involve the postulation of theoretical entities with those explanatory properties which are needed to explain the problematic properties of observable phenomena. Or, in the words of N. R. Hanson, to offer a scientific explanation is to offer 'an intelligible, systematic, conceptual pattern for the observed data'.[11] 'The value of this pattern lies in its capacity to unite phenomena which, without the theory, are either surprising, anomalous or wholly unnoticed'.[12] The same idea may be alternatively expressed in terms of the explanans-explanandum distinction. The pattern of scientific explanation is thus always a pattern of logical relationship between the explanans (in the form of a theoretical system) and the corresponding explanandum (in the form of the statement of more or less general relationships holding between observable properties of natural phenomena). In effect, it involves a pattern of *organization* of more or less general empirical statements describing *observable* aspects of natural phenomena in terms of theoretical systems describing *unobservable* aspects of natural phenomena.

As is generally recognized, the perceptibility of classical physical theories consists in the fact that ' they describe nature by models formed analogously to things that can be perceived by the senses '.[13] More precisely, they are perceptible in an extended sense of the term in that they can be shown to be attempted *representations* of non-perceptible (non-observable) physical processes ' in the image of the perceptible '.[14] This is best illustrated by the classical planetary model of the atom, which was first proposed by Rutherford and later adopted by Bohr for his theory of the hydrogen spectrum.[15] In the beginning Bohr ' postulated that Coulomb's law and Newton's law of motion hold for such an atomic system.'[16] It is clear that such a pattern of physical description at the level of atomic phenomena could have been dictated only by the perceptibility requirement through which the task of a physical theory was generally conceived to reduce all ntural phenomena ' to forces of attraction and repulsion '—i.e., to the laws of Newtonian mechanics.[17] To quote Hanson : ' .... the criterion for determining whether a physical theory was causal or mechanical was whether it could be pictured '.[18] In this way, in classical physics, describability came to be identified with picturability or perceptibility.[19]

The violation, in modern physics, of the perceptibility requirement and a consequent adoption of a non-classical pattern of physical description is beautifully illustrated by the modern elementary particle theory, whose equations do not lend themselves to any mechanical model on classical lines. For in this theory " phenomena are ' encountered ' which are neither causal, nor picturable, nor even mechanical in any classical sense."[20]

Einstein's general relativity theory provides an equally interesting example. Thus, like a photon or an electron, Einstein's finite, spherical (and hence non-Euclidean) universe, whose properties can be accurately dsecribed mathematically, cannot be represented by a model in terms of familiar, perceptible objects of ordinary experience. This is so precisely because this theory employs a group of gravitation laws which describe the field properties of the space-time continuum, and which violate the perceptibility requirement.[21]

An interesting example of a rather general violation of the perceptibility requirement is provided by the unifying *field* concept and the field laws of science. The field concept was first introduced into physics when Michael Faraday proposed an alternative formulation of Coulomb's law of electrostatic force in terms of the concept of the electric field.[22] In physics, such a conceptual innovation became necessary in order to explain diverse phenomena of so-called *action-at-a-distance*, which, as was realised, could not be subjected to a mechanistic explanation.[23] The departure from the classical pattern of physical description and a gradual geometrization of physics on the pattern of Einstein's general relativity theory, both the processes were initiated through this conceptual innovation. As is generally true of all non-mechanistic explanation, physical explanation in terms of fields is possible only by violating the classical perceptibility requirement. To different types of forces that are known to physics there correspond physical fields which are vector quantities and hence measurable with respect to their *direction*, *strength*, etc. But it must be admitted that they are essentially non-perceptible in character; although it is still customary in physics text-books to associate with fields of various type pictorial models/visualizations in terms of the socalled *lines of force*.[24]

This situation in modern physics permits a generalization over all other branches of science including social sciences. For the current scene in these sciences seems to be set for conceptual innovations more or less on the pattern of modern physics. Recent attempts to employ the field concept in developmental biology, e.g., should be of great philosophical interest in this context.[25] In general, the current scientific scene seems to be witnessing an increasing involvement of science with the problem of explaining phenomena of *organized complexity*, which are describable only in terms of non-classical concepts of systems-behaviour, multivariable interaction, organization, self-regulation, feedback control, and the like. Such phenomena are exemplified by natural systems ranging from atoms, through biological organisms to psycho-social systems of different orders of organized complexity.

The situation, it would seem, could not have for long been other than what it is now. Indeed it turns out that the essential nature or role of scientific explanation has no necessary connection whatever with imperatives of the type formulated by the perceptibility requirement. Incorporation of such an imperative into the foundations of classical physics can be traced to a certain confusion rather than any warranted considerations concerning scientific explanation. It may thus be admitted that 'only when the quest for picturability ended was the essence of explanation within all natural philosophy laid bare'.[26]

IV. Perceptibility Requirements as a Pragmatical Imperative

From the viewpoint of modern semiotic analysis it is worthwhile to look at the structures of classical and modern physics afresh. First of all, it is noteworthy that classical physics as a semantical structure came into being by way of a divergence from, and not by way of an extension of, Aristotelian physics on the one hand and the ordinary thing-language[27] on the other. It is this divergence which accounts for the distinct and relatively independent semantical structure of classical physics. Thus the type of physical processes, magnitudes, relations and forces which the theories like Newtonian mechanics and Maxwell's electrodynamics admitted to explain observable properties of physical phenomena can have no place whatever in the semantical structure of the descriptive framework either of Aristotelian physics or of ordinary thing language.[28] Revolutionary conceptual innovations of modern physics involve still more interesting strides in the direction of a progressive divergence-shift in respect of its semantical as well as pragmatical structure.

Again, it is a distinguishing feature of classical physics that, in spite of its relatively independent semantical structure, it borrowed its pragmatical matrix in large measure from the obeservationally committed descriptive framework of Aristotelian physics.[29] The latter may reasonably be regarded as an extension of the descriptive framework of the ordinary observational thing-language and hence as embodying a far stronger version of the perceptibility requirement. We may now turn to a discussion of his requirement itself.

The classical perceptibility requirement assumes quite dogmatically that the 'non-observable' or the 'non-perceptible' as postulated by a physical theory 'must have, at least basically, the same properties as the objects of perception'.[30] This shows that this requirement is bound to conflict with the general pattern of scientific explanation considered above. Rendered in precise semiotic terms, it expresses a *pragmatical* imperative which requires the semantical structure of a physical theory to be embedded in a pragmatical matrix of the type that operated most uncritically in Aristotelian physics and that is also in a sense characteristic of the ordinary observational thing-language. In effect, it requires the semantical structure of a physical theory to be *determined* or *restricted* according to a certain pragmatical matrix dogmatically assumed from the very beginning. In doing so it *assumes* mistakenly a certain logical order of *precedence* of the pragmatical matrix over the semantical structure of a physical theory. It is not surprising to see how this assumption gives rise to another equally mistaken assumption that the relationship of *inseparability* holding between a theory in the making and its natural pragmatical context *extends* upto its semantical/methodological contexts of description, explanation and theory-testing. Whatever may be the detailed nature of the underlying reasons in classical physics, such assumptions do not find any place in modern physics.

Both ' observability ' and ' perceptibility ' are in their usual and present senses pragmatical terms which are applicable to complex situations involving an intimate interplay between concepts/theories and their authors/users including their performances in applying them to concrete suituations. Such situations of interaction between a language and its users are clearly of primary interest only to pragmatics and therefore demand pragmatical analysis. It is true that such situations of interaction invariably accompany those situations in which language is employed for purely theoretical purposes of description and explanation. But, from the point of view of semiotic analysis it is of crucial importance that relations governing the pragmatical aspects of such situations are not extended to or confused with those that govern their semantical aspects, and *vice-versa.*

It may be more clear now that to require a physical concept or a theory to be perceptible in the extended sense considered before and to do so without necessary qualification is to commit the error of requiring the semantical structure of the throy to be determined according to an *assumed* pragmatical imperative, which in the present case is borrowed from Aristotelian observational phyiscs. It is also clear that such an imperative derives its apparent plausibility from the unstated, mistaken assumptions that (*a*) the pragmatical matrix of a physical theory must enjoy an overall *logical* precedence and dominance over its semantical structure, with the latter always embedded in the former in a crucial manner; and (*b*) the relations true of the former must also hold true of the latter.

The classical perceptibility requirement stands exposed now as a pragmatical imperative borrowed from Aristotelian physics and extended from its appropriate pragmatical domain to that of semantics. The relevance of such an imperative and some of its accompanying assumptions to psychologically investigative, inventive or creative situations is not so much in doubt. Relations true of such situations of interaction provide whatever justification is possible for it. But these pragmatical relations have no relevance whatever to contexts of scientific description, explanation and theory-testing. The pragmatical elements usually accompanying such contexts are a matter of contingent fact and hence dispensable in principle. The replacement of the human performer of these essentially non-pragmatical contexts by a sophisticated machine with all the desirable devices for it to operate is at least conceivable.[31]

That in classical physics the semantical and methodological questions concerning physical theory were frequently mixed up with the pragmatical ones is amply evident from the dogmatic manner in which *it* was subjected to a pragmatical imperative by requiring it to be perceptible. Non-perceptibility of modern physical theory can be explained only as a consequence of a rejection of this imperative in favour of an alternative which is appropriate to the general logical pattern of scientific explanation. In modern physics, the proper placing of the prgamatical and semantical aspects of a physical theory has become more necessary than ever before. The very idea of physical theory *without* perceptibility is instructive in pointing to a general methodological rule that *whatever may be the natural prgamatical setting of a scientific theory (in the making), its semantical structure cannot be, without serious error, required to be determined or restricted according to the essential features of that setting.*

V. Operationism, Empiricism and Alternative Pragmatical Imperatives

In this century, the most interesting attempt ever made to *embed* physical theory in imperatives of a pragmatical kind is Bridgman's operationsim as advanced in his *Logic of Modern Physics* (1927). It is necessary to note that Bridgman never intended his doctrine in the sense of a prgamatical imperative. ' Historically ', writes Frederick Suppe, ' the operational imperative was introduced to explain how theories legitimately could employ parameters which could not be directly observed or measured, and how theories describing phenomena in terms of such parameters could be tested and confirmed observationally '.[32]

On Bridgman's own formulation, operationism requires the meaning of a physical concept to be specifiable in terms of the ' operations ' which the physicist performs in applying the concept to a concrete situation; ' the concept is synonymous with the corresponding set of operations '.[33] The operational implications of a concept that are required to define its meaning are conceived of as involving an indispensable human performer of the operations. Thus, *assuming* explicit definition in terms of observables of some suitable kind to be the only legitimate method of introducing non-observable, theoretical concepts into science, operationsim requires the observables in question to the ' operational ' in character.

The resulting *pragmatical* character of the operational imperative is open to the criticism that it seeks to absorb the semantics of a physical theory into its pragmatics.[34] Here it is relevent to mention a more recent observation on the nature of the operational imperative by F. Suppe, who writes : ' .. the operational imperative is a prescriptive thesis about formulations of theories which implies restrictions on the sorts of theories science may employ '.[35] Other recent criticisms showing that operationism does not serve the purpose for which it was originally introduced do not concern us here.[36]

What is true of operationism can be shown to be equally true of the more general principle of contemporary logical empiricism. Like the former, the latter was also intended as a semantical imperative requiring the *restriction* of the semantical structure of the language of empirical science in accordance with the empiricist criterion of empirical significance.[37] The problem of accounting for the empirical significance and testability of scientific theories employing non-observable, theoretical parameters was construed as a problem of restricting these theories to those that would satisfy the empiricist criterion. In their turn, successive formulations of the empiricist criterion all sought to solve essentially a semantical problem by invoking pragmatical imperatives in terms of the pragmatical concepts of verifiability and observability.

Rejection of operationism and the principle of empiricism as pragmatical imperatives is warranted by the same considerations as warrant the rejection of the classical perceptibility requirement. For, as their analysis reveals, each invokes a pragmatical imperative to restrict the semantical structure of scientific theories in a crucial, though dogmatic, manner. Each is bound to prevent rather than promote the progress of conceptual innovation in science.

Two questions arise at this point for further consideration : (i) What is the proper place or role, if any, of pragmatical imperatives in science ?; and (ii) What other pragmatical impérative/s appropriate to the nature of modern physical theory may be admitted to replace in some sense the ones that must be rejected ? To take the latter question first, there are reasons to ansewer it in the affirmative. Violation of a particular pragmatical imperative must sooner or later lead to some alternative or another. For a physical theory or a scientific theory in general cannot be denied its pragmatical setting involving distinct pragmatical relations between it and its authors and users.

In his *Principles of Quantum Mechanics* (1930) P.A.M. Dirac suggested the ' extending ' of the meaning of the word ' picture ' to include ' any way of looking at the fundamental laws which makes their self-consistency obvious '.[38] When he made this suggestion, he had in mind the laws of the quantum theory which violate the pragmatical imperatives of the type considered above. On this suggestion, then, to acquire a ' picture ' of atomic phenomena is to acquire a sufficient degree of ' familiarization ' with the laws of this theory in Dirac's sense.[39] It seems that the point of this valuable suggestion can be appreciated better if it is interpreted as an attempted replacement of the older pragmatical imperatives by an alternative which is appropriate to the nature of modern physical theory. For, it may be argued, any way of looking at the laws of the quantum theory which makes their self-consistency *obvious* will be essentially a non-classical way of the required *familiarization process*. Dirac's suggestion may thus be reformulated in the form of a pragmatical imperative requiring the structure of a physical theory to be susceptible to a familiarization process in the sense of Dirac.

It is of some interest to compare this formulation with the usual formulations of the classical perceptibility requirement whose essential pragmatical character remained almost burried under the confusion characteristic of classical physics—the confusion between the pragmatical and semantical aspects of physical theory. This may explain why it was always invoked in the non-pragmatical contexts of physical explanation and theory–testing. It is clear that the only legitimate aim of introducing such a requirement could have been the familiarization process in a much stronger sense than Dirac's. But this is precisely what was lost sight of by its staunchest advocates within science. Operationsim and the principles of contemporary logical empiricism both repeat the same mistakes all over again.

We may now turn to the more general question of the proper place of pragmatical imperatives in science.

VI. Consequences for Science and Philosophy

In the light of the general pattern of scientific explanation considered above it is clear that the pragmatical imperatives of the perceptibility requirement, operationism and the principle of empiricism all put physical science into fetters. For each seeks to restrict the type of theory which physical science may employ for purposes of explanation. In each case, the principle according to which this restriction is sought to be effected turns out to be essentially an imperative of a pragmatical kind. It would thus seem that at present, Dirac's pragmatical imperative provides the most liberal and suitable alternative to them.

The non-perceptibility of modern physical theory together with its mathematical character is an important advance in the growth of scientific methodology, at least from the viewpoint of the kind of objectivity science generally aims at.[40] The revolution in physics in this century would not have been possible without violating the classical perceptibility requirement. The situation in modern physics is thus instructive in that it throws some valuable light on the nature of pragmatical imperatives and their place in empirical science. It cannot be denied that pragmatical and extra-pragmatical imperatives are always in operation in a science. But it is mistaken to suppose that the former enjoy any logical precedence or dominance over the latter, as was supposed in classical physics. Thus the situation in modern physics warrants the view that : (*a*) the proper function of pragmatical imperatives is to take care of the pragmtaical relations that emerge *after* a more or less confirmed, newly discovered theory sets a fresh and useful pattern of explanation for some set of problematic phenomena; and (*b*) the development and formulation of such imperatives must take into account, and proceed in ways appropriate to, the semantical structure of the new theory. On this view, pragmatical imperatives are *relative* to the general scene of semantical relations[41] characteristic of a particular field of science at a given time and not *vice-versa*. They are thus variable with variations taking place in this scene. Both (*a*) and (*b*) seem to be satisfied by Dirac's pragmatical imperative as reformulated above.

The consequences of our discussion for philosophy seem equally interesting. Historically, there has been an intimate conncetion between epistemology on the one hand and the pragmatical imperatives of the type expressed by the classical perceptibility requirement and operationsim on the other. From the customary formulations and discussions of the problems of knowledge it is quite clear that, whatever may be their major differences, philosophers of both rationalist and empiricist traditions employ a common concept of epistemology. Thus epistemology is invariably conceived of subjectivistically by formulating its central problems in pragmatical terms like 'experience', 'perception', 'belief', 'reason', 'doubt', 'certainty', 'intuition' and so on endlessly. In this way epistemology has remained tied to the pragmatical aspects of the theoretical use of language even to this day. Pragmatical imperatives operating in empirical science from time to time have had their own share of contribution in reinforcing this subjectivist tradition in epistemology. This is clearly illustrated by epistemologies associated with the eighteenth century British empiricism on the one hand and contemporary operationism and logical empiricism on the other.

With the changed situation in modern physics, the philosophical implications of science generally turn out to be of a nonclassical nature. Whatever may be their historical interest and importance, the classical empiricist and rationalist theories of knowledge have no relevance whatever to the contemporary scene. Modern physical science set the scene for a complete break with classical epistemology which has concentrated on the pragmatical aspects of the theoretical use of language. Such a changeover entails its replacement by an objectivist epistemology which would instead concentrate on the semantics and methodology of science.[42] Important beginnings, forming an important part of contemporary philosophy of science, have already been made in this direction. It must be recognized that the credit for preluding the departure from classical epistemology goes in large measure to modern physical theory.

VII. Conclusion

Imperatives requiring empirical science to employ one type of theory rather than another have always accompanied the body of general assumptions with which it, as a rule, operates from time to time. The variety of these imperatives is evident from the fact that they range from general requirements of a pragmatical and semantical kind to those of a methodological kind. Depending on the specific complexity of the subject-matter and the degree of theoretical organization characteristic of a science at a given time, some of these imperatives may vary from one field of science to another. It is not surprising that the rate and direction of the growth of the *system* of scientific knowledge should in large measure depend on the specific nature of these imperatives and their effectiveness in actual scientific research. What seems to have escaped notice, however, is the fact that powerful hindrances in the way of this growth have often arisen from within science through dogmatic elements operating in the guise of these very imperatives. The reason why this has actually been so with science (e.g., classical physics) may plausibly be sought in the fact that there is always the possibility of confusion between dogma and legitimate imperatives of science on the one hand and between type-distinct imperatives of science on the other. Such a situation clearly warrants a detailed philosophical study of the nature of such imperatives and their respective legitimate roles in empirical science. The main purpose of such a study must be the development of a general theory of imperatives, which would enable one to distinguish improper imperatives from imperatives which are proper to science.

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NOTES

1. Cf. K. Menger, " Modern Geometry and the theory of Relativity", in P. A. Schilpp (ed.) *Albert Einstein : Philosopher Scientist*, New York, 2nd ed., pp. 464–65.

2. Cf. W. Heitler, "The Departure from Classical Thought in Modern Physics", *op. cit.*, p. 181.

& H. Reichenbach, " The Philosophical Significance of the Theory of Relativity", *op. cit.*, pp. 293–95.

3. Cf. D. Bohm, *Causality And Chance in Modern Physics*, London, 1957, pp. 68–69.

& A. Eddington, *The Philosophy of Physical Science*, Cambridge Universiy Press, 1949, pp. 63–64, 90–94.

4. The former requires science to employ mutually inconsistent theories simultaneously as a means to promote the discovery of ever better alternatives to the existing theories in different fields. Whereas, the latter ' demands that at any time only a single set of mutually consistent theories be used '. For details see P. K. Feyerabend, "Problems of Empiricism", in R. G. Colodny (ed.) *Beyond the Edge of Certainty*, Prentice–Hall, INC., Englewood Cliffs, N. J., 1965, pp. 149–153.

5. See E. L. Hill, " Quantum Physics and the Relativity Theory", in H. Feigl, et al. (eds.) *Current Issues in the Philosophy of Science*, Holt, Rinehart and Winston, 1961, pp. 429–30.

& N. R. Hanson, *Patterns of Discovery*, The Scientific Book Guild, 1962, p. 126.

6. N. R. Hanson, *Ibid.*, p. 91.

7. See : *Ibid.*, p. 91

& A. Einstein and L. Infeld, *The Evolution of Physics*, 2nd ed., Cambridge Univ. Press, 1961, pp. 152–53.

8. Cf. N. R. Hanson, *Ibid.*, pp. 119, 126.

9. See R. Carnap, *Introduction to Symbolic Logic and Its Applications*, New York, 1958, pp. 78–79.

& C. W. Morris, *Foundations of the Theory of Signs*, University of Chicago Press, 1938.

10. Cf. N. R. Hanson, *op. cit.*, pp. 119, 121.

11. *Ibid.*, p. 121.

12. *Ibid.*, pp. 121-122.

13. See C. F. V. Weizsacker, *The World View of hysics*, (Transl. by Majorie Grene), London, 1952, pp. 13, 29–31, 93.

14. Cf. *Ibid.*, p. 30.

15. For details see F. W. Constant, *Fundamental Laws of Physics*, London, 1963, pp. 69, 311.

16. *Ibid.*, p. 311.

17. Cf. N. R. Hanson, *op. cit.*, p. 91.

18. *Ibid.*, p. 91

19. *Ibid.*, p. 91.

20. *Ibid.*, p. 92; See also W. Heisenberg, " Fundamental Problems of Present-day Atomic Physics ", in P. P. Wiener (ed.) *Readings in Philosophy of Science*, New York, 1953, pp. 91, 96.

21. See A. Einstein, *Relativity* (Transl. by R. W. Lawson), Methuen & Co. Ltd., 1960, pp. 108, 113–114; E. Whittaker, *From Euclid to Eddington*, Cambridge, 1949, pp. 10, 116–17, 188.

22. See F. W. Constant, *op. cit.* p. 204.

.3. See *Ibid.*, p. 204; A. Einstein and L. Infeld, *op. cit.*, pp. 151, 244.

24. For example, the lines of force of the sun's gravitational field that is said to radiate ' out in all directions away from the sun '. See F. W. Constant, *op. cit.*, p. 69.

25. See, e. g., C. H. Waddington; " Fields and Gradients ", in Michael Locke (ed.) *Major Problems in Developmental Biology*. New York, London, Academic Press, 1966, pp. 105–123.

26. N. R. Hanson, *op. cit.*, *p.* 126.

27. For a clear conception of ordinary, thing–language see R. Carnap, *Meaning and Necessity*, Phoenix Books, Chicago, 1956, pp. 206–208

28. Cf. P. K. Feyerabend, *op. cit.* pp. 155, 232–233. To quote Feyerabend (*Ibid.*, p. 155) : ' Aristotelian physics is quite explicitly observational, to be observable is part of the difinition of physical nature it uses. The constitutive forms of physical objects are required to be observable...The empiricist epistemology of the Aristotelians and their physics are in harmony '.

29. Cf. P. K. Feyerabend, *Ibid.*, pp. 155, 232.

30. Cf. C. F. v. Weizsäcker, *op. cit.*, p. 95.

31. Cf. P. K. Feyerabend, "Science Without Experience", *The Journal of Philosophy*, Vol. LXVI, No. 22, Nov. 20, 1969, pp. 792.

32. F. Suppe, "Theories, their Formulations, And the Operational Imperative", *Synthese*, Vol. 25, Nos. 1/2, Nov./Dec. 1972, p. 135.

33. P. W. Bridgman, *The Logic of Modern Physics*, New York, 1927, p. 5.

34. See A. Grünbaum, "Operationism and Relativity", in P G. Frank (ed.) *The Validation of Scientific Theories*, New York, 1961, pp. 83-91.

35. See F. Suppe, *op. cit.*, p. 159.

36. See, e. g., *Ibid.*, pp. 129–164.

37. For example, Carnap's ("Testability and Meaning", *Phllosophy of Science*, Vol. III. 1936 and Vol. IV, 1937) explicit reformulation of the principle of empiricism as a general requirement precisely in this sense is noteworthy. See R. Carnap, *Testability and Meaning*, New Haven, Connecticut, 1954, Part IV, p. 33.

38. P.A.M. Dirac, *The Principles of Quantum Mechanics*. revised, 4th ed., Oxford, 1958, p. 10.

39. Cf. *Ibid.*, p. 10.

40. Cf. M. Born, *Natural Philosophy of Cause and Chance*, New York, 1964. p. 214.

41. For a recent provoking theory of these semantical relations See F. Suppe, *op. cit.*, pp. 136–144.

42. For an excellent discussion of the problem of 'subjectivist vs. objectivist epistemology' see K. R. Popper, "Epistemology Without a Knowing Subject", in B. V. Rootsellaar, *et. al.*, (eds.) *Logic, Methodology and Philosophy of Science* III, Amsterdam, 1968.