

THE PROLIFERATION AND SYNTHESIS OF PHYSICAL THEORIES

Tremendous progress has been achieved in the theoretical understanding of entire groups of new phenomena, but the establishment of a unified basis of physics as a whole seems an occupation for the remote future. And this state of affairs has been aggravated by the following development!
Albert Einstein

The step by step conquering of physical knowledge is worth noting. Taken as a whole, such knowledge constitutes the physical world, which includes a number of classes of “phenomena” (and their natures).

For a long period of time physics (and science in general), as is well known, was represented by mechanics, which was regarded as a comprehensive theory of the world, such that reality itself was considered to be mechanical in its essence.¹

Significant progress in physical (and scientific) knowledge has been made through the transition from one universal (physical, or mechanical) theory to a group of (basic) theories, to which mechanics also belongs (but already with a correspondingly limited domain of validity). This corresponds to the penetration of knowledge into new areas, and the revealing of their particularities.

At this stage the view of the existence of so-called closed physical theories, which are characterized by a particular system of concepts and laws, emerges. Each of these theories gives rise to a ramified system of derivative theories.

Along with this, in every physical domain – mechanics, field physics, etc., alternative theories are framed. Thus we observe a markedly expressed process of differentiation or proliferation of physical theories.

The establishment of inter-theoretical links between these theories, and their syntheses into more general theories, goes hand in hand with this process.

This trend of bridging physical theories as they grow in number (which we will try to elucidate in greater detail) may be considered as a concretization of the more general divergent-convergent course of scientific knowledge in solving scientific problems.

1. THE PROLIFERATION OF PHYSICAL THEORIES.

Closed Theories. In our time the view has been formed that there are several basic independent physical theories that are characterized by specific concepts and laws. Aside from this, they are conceived as complete in principle, i.e., they are not to be

subject to improvement through minor changes. In this context Heisenberg introduced the concept of “closed (abgeschlossene) theories”.²

In keeping with this conception Weizsäcker³ adheres to the following general scheme of (five) mutually connected physical theories, which either exist or are in a state of being framed:

1. The theory of space-time (the special or possibly the general theory of relativity);
2. General mechanics (quantum theory);
3. The theory of the possible types of objects (theory of elementary particles);
4. The theory of irreversibility (statistical thermodynamics);
5. The theory of the universality of physical objects (cosmology).

The theory of elementary particles, which is in a process of formation, has been included along with the existing physical theories. Unlike theories 1, 2 and 4, which are almost completed, the framing of 5 may still be considered an open problem.

Tisza's attempt at systematizing (“structuring”) physical theories is of interest.⁴ He considers the fundamental physical branches (mechanics, thermodynamics, quantum mechanics) as clusters of deductive systems; or, in other words, the basic discipline is represented by more than one (supplementary) system. In this way he distinguishes among a classical mechanics of particles, a classical mechanics of particles under a microscopic interpretation, and a phenomenological classical mechanics. Analogously, according to him, thermodynamics is represented also by a macroscopic equilibrium thermodynamics, a statistical equilibrium thermodynamics, a macroscopic thermodynamics and a statistical thermodynamics. Along with quantum mechanics, quasi-static quantum mechanics and quantum dynamics are also included here. Some of these systems (quantum dynamics, statistical thermodynamics, and macroscopic thermodynamics) are essentially incomplete.

This system also includes classical gravitational theory, classical electrodynamics, relativistic mechanics and relativistic gravitational theory. Altogether there are eight theories and three other incomplete systems.

Tisza examines the different relations between these systems, namely those of compatibility, controlled inconsistency, and supplementarity, as well as the incompletely understood relation.

Derivative Theories. The basic (closed) theories comprise various branches; derivative theories are built up on their basis. Thus, along with the dynamics of mass points, the system of mass points, and the dynamics of solids, theories have been created covering continuous media (fluids and gases), hydrodynamics, aerodynamics and gas dynamics, the dynamics of deformable solids, elasticity and plasticity, as well as celestial mechanics, perturbation theory, aircraft dynamics, rocket dynamics, hydraulics, the dynamics of machines and mechanisms, and so on.

Field theory as a general trend may be represented by the theory of the electromagnetic field, and the theory of gravitation. From these theories, the electrodynamics of continuous media, cosmology, and so on, are formed.

Within the framework of thermodynamics, the theory of phase transition, the theory of surface phenomena, etc. are created. The thermodynamics of magnetic phenomena, the thermodynamics of superconductivity, the statistical thermodynamics of solids, and so on, are elaborated on the basis of thermodynamics.

Quantum theory embraces: the quantum, many body theory, statistics, radiophysics (electronics), the theory of magnetism, field theory, electrodynamics, the theory of heat absorption, the theory of crystals and solids, of their electricity and heat-conductivity, of their magnetic properties, the theory of semiconductors, of superfluidity, of superconductivity, quantum chemistry, etc.

This process of building up derivative theories is denoted as extensive development of the theory.⁵

Classifications of Physical Theories. The set thus formed of (several dozens of) physical theories is the subject of various classifications. Among the different attempts of this kind we shall note the following approaches (which are of interest in our case):

A) We consider first *Einstein's* approach, where one distinguishes between constructive theories and theories of principle (fundamental theories).⁶ To the former belong theories like the kinetic theory of gases, wherein a picture is given of complex phenomena on the basis of relatively simple assumptions. The theories of principle proceed from empirically observed general properties of phenomena, respectively from principles by means of which (mathematical) criteria with a universal validity are formulated. The analytical method is used in them. Examples of such theories are thermodynamics and the theory of relativity.

The constructive theories, according to Einstein, are distinguished by their comprehensiveness, adaptability and clarity; and those of principle, by their logical perfection and the security of their foundations. If any deduction from a theory should prove untenable, the theory must be given up. A modification of it seems impossible without its destruction as a whole.

B) Concerning theories in general (not only physical theories) *Rapoport* distinguishes seven groups,⁷ of which we shall consider the first three (which have a bearing on physical theories).

1. Intrinsically mathematical theories, which involve something analogous to the notion of a state, and describe a state-transition mechanism ("equation of motion"), e.g., quantum mechanics.

2. Theories that are like those of the first group except that they contain no state transition mechanism, such as thermodynamics, crystallography, and classical optics.

3. Stochastic theories, which are mathematical and quantized but in which the basis of quantizing is computation rather than measurement; such theories generally do not involve a notion of state, employing rather the notion of an event.

C) In *Madelung's* classification the following (seven) kinds of physical theories are distinguished: point (e.g., point mechanics); quasi-point (mechanics of bodies); continuum (field theory); quasi-continuum (hydrodynamics); combined point and



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