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Classic texts: extracts from Curie and Weyl

On symmetry in physical phenomena, symmetry of an electric field and of a magnetic field

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I. Introduction

I think that there is interest in introducing into the study of physical phenomena the symmetry arguments familiar to crystallographers.

For example, an isotropic body may have a rectilinear or rotational motion. If liquid, it may have turbulence. If solid, it may be compressed or twisted. It may be in an electric or magnetic field. It may carry an electric or thermal current. It may be traversed by unpolarized or linearly, circularly, elliptically, etc. polarized light. In each case a certain characteristic asymmetry is necessary at each point of the body. These asymmetries are even more complex if one assumes that several phenomena coexist in the same medium or if they take place in a crystallized medium, which already possesses, by its constitution, a certain asymmetry.

Physicists often utilize symmetry conditions, but generally neglect to define the symmetry in a phenomenon, for sufficiently often these symmetry conditions are simple and quite obvious *a priori*.

When teaching physics, it would be better to state these questions openly: In the study of electricity, for example, one should state almost immediately the characteristic symmetry of the electric field and of the magnetic field. One can then use these notions to simplify proofs.

From a general point of view the idea of symmetry can be linked to the concept of *dimension*: These two fundamental concepts are respectively characteristic of the *medium* in which a phenomenon occurs and the *quantity* which serves to evaluate its intensity.

Two media with the same asymmetry have a particular link between them, from which one can draw physical conclusions. A connection of the same kind exists between two quantities of the same dimension. Finally, when certain causes produce

Note. Extract from: 1982, *Symmetry in Physics: Selected Reprints*, ed. J. Rosen, trans. J. Rosen and P. Copié, Melville, NY: American Association of Physics Teachers, pp. 17–25.

certain effects, the symmetry elements of the causes must be found in the produced effects. Similarly, when a physical phenomenon is expressed as an equation, there is a causal relation between the quantities appearing in both terms and the two terms have the same dimension. . . .

IV. Characteristic asymmetry of physical phenomena

Let us now consider any point of a medium in any physical state . . .

We state the following propositions.

The characteristic symmetry of a phenomenon is the maximal symmetry compatible with the existence of the phenomenon.

A phenomenon can exist in a medium which possesses its characteristic symmetry or that of one of the subgroups of its characteristic symmetry.

In other words, certain symmetry elements can coexist with certain phenomena, but they are not necessary. What is necessary is that some symmetry elements be missing. *Asymmetry is what creates a phenomenon.*

It is much more logical to call a plane of asymmetry any plane that is not a plane of symmetry, to call an axis of asymmetry any axis that is not an axis of symmetry, and so on, and in general to list the operations which are not recovery operations in the system. These are the operations indicating an asymmetry and therefore a possible property of the system. But in the groups we considered there are an infinite number of nonrecovery operations and in general a finite number of recovery operations: It is thus much simpler to list the latter operations.

One can also see that when several different phenomena are superimposed in the same system, their asymmetries add. The symmetry elements remaining in the system are only those that are common to all phenomena taken separately.

When certain causes produce certain effects, the symmetry elements of the causes must be found in their effects.

When certain effects show a certain asymmetry, this asymmetry must be found in the causes which gave rise to them.

In practice, the converses of these two propositions are not true, i.e., the effects can be more symmetric than their causes. Certain causes of asymmetry might have no effect on certain phenomena or at most an effect too weak to be discerned, which amounts to the same as no effect, for practical purposes. . . .

VII. Conclusion

The characteristic symmetries of phenomena are of incontestable general interest. From the point of view of applications we see that the conclusions we can draw from symmetry arguments are of two kinds.

The first are firm but negative conclusions. They correspond to the incontestably true proposition: *there is no effect without causes.* Effects are phenomena which always require a certain asymmetry in order to arise. If this asymmetry does not exist, the phenomena are impossible. This often prevents us from searching for unrealizable phenomena.

Symmetry arguments also permit us to state a second kind of conclusions, which are of positive nature but do not offer the same certainty of their results as those of negative nature. They correspond to the proposition: *There is no cause without effects.* Effects are the phenomena which can arise in a medium possessing a certain asymmetry. One has here precise directions for the discovery of new phenomena, but the predictions are not as precise as those of thermodynamics. One has no idea of the order of magnitude of the predicted phenomena. One has only an imperfect idea of their precise nature. This last remark shows that one should beware of drawing an absolute conclusion from a negative experiment

Let us consider, for example, a tourmaline crystal which possesses a symmetry which is a subgroup of the electric field symmetry. We conclude that the crystal may be electrically polarized. We place the crystal in an electric field, its axis oriented 90° to the field; no polarization is observed in any way. One has no measurable torque acting on the crystal. One would be tempted to think that the crystal is not polarized, or that, if there is a polarization, it is less than what one can observe. Yet, there is a polarization and to make it appear it is necessary to modify the experiment, to heat the crystal uniformly, for example, which does not change its symmetry.

Symmetry

HERMANN WEYL

This is a special case of the following general principle: If conditions which uniquely determine their effect possess certain symmetries, then the effect will exhibit the same symmetry. Thus Archimedes concluded *a priori* that equal weights balance in scales of equal arms. Indeed the whole configuration is symmetric with respect to the midplane of the scales, and therefore it is impossible that one mounts while the other sinks. For the same reason we may be sure that in casting dice which are perfect cubes, each side has the same chance, $\frac{1}{6}$. Sometimes we are thus enabled

Note. Extract from: 1952, Princeton, NJ: Princeton University Press, pp. 125–6.