The Existence of Space and Time

I. Hinckfuss
153 pp. Oxford U. P., New York, 1975. $11.25

What does it mean to affirm or deny the existence of space and time? Ian Hinckfuss, a lecturer in philosophy with previous education in mathematics and physics, provides an elementary introduction to this and other philosophical problems. By avoiding the technicalities of physics and philosophy, he has produced a book that is readable by students of either subject.

Theories of the nature of space range between the extremes of absolutism and relativism. According to the former view, space is an entity (though perhaps not a material substance) with properties of its own; for example, space possesses an electric permittivity of 8.55×10^{-12} farads per meter. On the other hand, the relationist view is that no such *entity* as space exists and all statements that appear to ascribe properties to space can be reduced to statements about relations between objects. To say that "space" exists is just to say that something is at a distance from (that is, in a space-like relation to) something else. Throughout the book, Hinckfuss argues that this relationist reduction can always be carried out, but he does not state clearly whether or not he considers such a reduction to be desirable.

For the relationist, the propagation of electromagnetic radiation poses a typical problem. Light travels at the speed $c = 3 \times 10^8$ meters per second. But with respect to what—to empty space? The relationist position is saved by defining *absolute motion with speed v* as motion with speed v relative to anything whatsoever, regardless of that thing's motion relative to any third thing. Thus, in accordance with special relativity, radiation moves with absolute speed c, but absolute motion does not imply absolute space as a reference frame.

The philosophical problems of time include whether and how it is distinct from space; the nature of the distinction among past, present and future; and the apparently unidirectional "flow" of time. The last of these involves very difficult, unsolved problems of physics as well as philosophy, so it is not surprising that this is the weakest part of the book. However, the author's discussion of statistical irreversibility is inexcusably poor. For example, he asserts that the probability for a solar system like ours to form from the condensation of a cosmic dust cloud is vanishingly small. In fact many scientists believe that such an event, and even the subsequent evolution of life, has a very high probability of occurring many times in the universe. The point is that the estimation of such probabilities is a very difficult problem, the solution of which cannot be presupposed in a philosophical argument.

Unfortunately the book does not treat Einstein's general relativity. In that theory, space–time has properties of its own (such as curvature), and it acts upon and is acted upon by matter. In spite of its name, general relativity poses a more serious challenge to the purely relational concept of space–time than did any earlier theory.

LESLIE E. BALLENTINE
Simon Fraser University
Burnaby, British Columbia
Canada

Anomalous Scattering

S. Ramaseshan, S. C. Abrahams, eds.
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Anomalous Scattering constitutes the proceedings of an international conference with that title held in Madrid in April of 1974. The credentials of the publisher (International Union of Crystallography) and the editors (S. C. Abrahams, Bell Telephone Laboratories, Murray Hill, N. J., and S. Ramaseshan, National Aeronautical Lab., Bangalore, India) are first rate. As opposed to many other hard-cover conference proceedings, *Anomalous Scattering* does not smack of commercialism. The intent, both by the International Union and the editors, was to provide a collection of material useful to the crystallographer and the diffraction physicist.

Anomalous scattering in its simplest approximation is that contribution to an atom's scattering amplitude attributable to discrete energy states of that atom. For x rays this means that the atomic scattering factor has an additional term (in general, complex) that is absent when the incident-beam energy is very far from any absorption edges of the atom (for certain gamma rays this could include both electronic and nuclear levels). For neutron diffraction this would involve neutron resonances in the thermal range.

Why is anomalous scattering useful in the determination of crystal structures? Interestingly, and somewhat surprisingly, the diffraction pattern of a crystal of any symmetry is always centrosymmetric if we are not in the regime of anomalous scattering; this is a formal statement of Friedel's law. This remarkable result says that the diffraction pattern of a crystal with a double helix, such as DNA, as its basic structural unit will produce a pattern that shows complete centrosymmetry. When the energy of the incident radiation approaches a critical edge of one of the atoms of the structure, anomalous scattering can produce a pattern no longer centrosymmetric.

A simple application of this technique takes place in the determination of the polar axis in a semiconductor-device material such as gallium arsenide. Gallium arsenide can be derived from the diamond structure by replacing alternate body-diagonal planes with gallium and arsenic atoms. The gallium–arsenic spacing differs from that of arsenic–gallium as one proceeds into the crystal in the body-diagonal (111) direction. Proceeding along this direction from a given face of the crystal, one sees a sequence Ga–As (space) Ga–As. Entering the crystal from the opposite sense, the sequence appears as As–Ga (space) As–Ga. The crystal is thus unidirectional and possesses a polar axis.

Given a parallel slab of gallium arsenide bounded by body-diagonal planes, one can, through anomalous scattering, determine which end is up. That is, the "absolute configuration" of the atomic arrangement can be related through anomalous scattering with some physical property of the macroscopic crystal. The faces of the above crystal would in general show different behavior under chemical etching. One face, say the A face, would display a characteristic array of triangular pits. The B face would also have pits of three-fold symmetry, but these would have a different morphology from those in the A face. Thus, one could readily identify the A face by chemical etching, but it would only be through a technique such as anomalous scattering that one could establish in an absolute sense which of the two sequences of layering was actually associated with this face.

In its more esoteric form, anomalous scattering can give important information to aid in determining crystal structures. In x-ray crystallography one experimentally determines the intensities of many Bragg reflections. Each intensity is proportional to the square of the amplitude of a Fourier coefficient whose related Fourier series constitutes a spatial representation of scattering matter within the three-dimensional crystal. In order to reconstruct the crystal mathematically and hence "determine its structure," one needs to know not only the magnitude of the Fourier coefficients but also their relative phases. Anomalous scattering techniques provide additional information that helps the crystallographer to make intelligent guesses of these relative phases.

One technique used by crystallographers consists of isomorphous substitution. In this case the crystallographer tries to obtain a derivative compound of the structure he is after by substituting heavier atoms in known places in the crystal without appreciably altering the arrangement of the original atoms. The heavier atom represents a strong amplitude of scattering; when added to the scattering of the relatively light atoms, it produces intensity information related to the relative phases of the atoms in the