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CONCEPTS OF MASS IN CLASSICAL AND MODERN PHYSICS. By MAX JAMMER. Cambridge, Harvard University Press, 1961. Pp. 230. $6.00.

With the publication of the present book the author completes his useful and important trilogy on the foundations of physics, the earlier two volumes being *Concepts of Space* and *Concepts of Force*. The three books together constitute perhaps the most detailed and authoritative historical analysis of space, force, and mass in the contemporary literature of the history and philosophy of science. Because the philosophical and historical analysis of physical concepts spreads out into mathematics on one side and epistemology on the other, readers with specialist interests will inevitably find points to quarrel with in Jammer's treatment of mass. In view of the breadth of coverage and the considerable erudition of the author, however, it will be an unusual reader indeed who does not learn a number of new things from reading Jammer's book.

The fourteen chapters divide up the subject matter as follows. The

first chapter contains an interesting etymological discussion of the word "mass." Chapters 2 and 3 deal with ancient concepts of mass and their absence; Jammer rightly argues, for example, that Aristotle had no proper concept of mass in his physics. The idea of conservation or invariance of mass seems foreign to Aristotle's concept of matter, closely related as it is to organic growth and decay. Chapters 4 and 5 trace the development of the concept of inertial mass from that of *quantitas materiae* in medieval thought. The tangled and often conceptually tortuous history from Buridan to Kepler to Newton should serve as encouragement to philosophers who despair of ever obtaining a clear systematic theory of concepts like those of intention which now seem very difficult to analyze satisfactorily. Chapter 7 describes the systematization of the concept of mass in the seventeenth century. As would be expected, Newton's role is predominant, although Jammer gives appropriate credit to Descartes. (I personally like to think of Descartes's *Principia* as the last of the great medieval treatises on physics, and Newton's *Principia* as the first great modern one.)

Chapters 7, 8, and 9 outline the refinement of the concept of mass within classical mechanics in the period since Newton. The author includes quite a thorough discussion of the definability of the concept of mass in axiomatized mechanics. There are two regrettable omissions. One is reference to the excellent recent work of Walter Noll on the concept of mass in continuum mechanics, and the other is a critical review of the muddleheaded literature on operational definitions of mass. The formal methods that have been applied to axiomatizations of physical theory also provide tools for the analysis of the relation between concepts and experimental procedures, but Jammer does not seem very aware of these possibilities. Perhaps a better way of putting it is that he does not seem properly critical of the intrinsic vagueness and analytic superficiality of the operational approach of Mach and his successors.

The remaining chapters, although useful contributions to the recent history of physics, are of less philosophical interest. Chapter 10 discusses the gravitational concept of mass, Chapter 11 the electromagnetic concept of mass, Chapter 12 the relativistic concept of mass, Chapter 13 the relation of mass and energy, and Chapter 14 the concept of mass in quantum mechanics.

I suppose what will most bother philosophical readers of this book is that the breadth of coverage is not always matched by a corresponding depth of analysis. For example, only slightly more than three pages (pp. 81-84) are devoted to Kant's subtle doctrine of matter and mass

as set forth in the *Metaphysical Foundations of Natural Science*, less than two pages (pp. 87-89) to Euler's important *Mechanica*, two pages (pp. 104-105) to Hertz's *Principles of Mechanics*. Perhaps in a later edition the author will find it feasible to expand his treatment of the more important figures in the history of the concept of mass.

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