Max Jammer, *Concepts of Simultaneity: From Antiquity to Einstein and Beyond* (Baltimore: Johns Hopkins, 2006)

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Max Jammer's recent book, *Concepts of Simultaneity: From Antiquity to Einstein and Beyond*, traces the history of our ideas on simultaneity as they evolved alongside sweeping changes in our understanding of physics. One of the interesting lessons of the book is that, even as our physical theories have become increasingly successful, the question of the proper *understanding* or interpretation of those theories remains extremely puzzling.

The central issue is this: Is the simultaneity of events a real feature of the world? Or does it depend on the particular choice of reference frame, with any such frame as good as any other?

In ancient times, Jammer suggests, most people took the notion of simultaneity for granted: Two events were simultaneous if they happened at the same time. Simultaneity was considered an objective feature of the world. This simple idea appeared confirmed by classical Newtonian mechanics. In Newtonian physics different inertial reference frames (ones that move at a constant velocity relative to one another) are equally good (the laws of motion hold in all of them), even though some attributes of an object, say velocity or momentum, differ from one reference frame to another. However, some features, such as simultaneity, hold in all allowable reference frames and are thus frame *in*dependent and in some sense more *objective*.

But what if two events whose simultaneity is in question took place far from each other? How would you know whether they were simultaneous? One solution (available for the last few centuries anyway) is for the observers of each event to look at their (previously synchronized) clocks. The question then becomes, How can clocks that are distant from one

another be synchronized? That is the issue that sparked Albert Einstein's special theory of relativity, in which he shocked the world by arguing that the interval of time between two events depends on the motion of the observer. One observer might perceive two events as happening at the same time, whereas another, who is moving relative to the first, might view the two events as happening in succession. Thus simultaneity is "relative" to the observer's frame of reference. Just as a toddler, my brother and a professional basketball player would give different, equally legitimate, answers to the question of whether or not I am tall, so too would observers in different inertial reference frames give different, equally legitimate answers to questions about whether particular events are simultaneous. According to special relativity theory, intervals of time in general, and simultaneity in particular, are "merely" frame-dependent quantities.

Simultaneity gets even murkier with the advent of general relativity and quantum mechanics. In general relativity, different kinds of spacetime are possible, not just the "flat" one of special relativity. Still, it seems that in any of these spacetimes, simultaneity will be a frame-dependent quantity. Yet quantum mechanics throws another complication into the mix. The so-called "collapse of the wave function" is supposed to occur at the same time in *all* frames of reference. In a now-famous paper written in 1935, Einstein, Boris Podolsky and Nathan Rosen pointed out this puzzling aspect of the theory: In quantum mechanics, a measurement done on a particle *over here* can immediately determine the outcome of a measurement done on a particle *over there*—even though these events occur simultaneously, so that there can be no interaction between the two particles in the meantime, and even though, before the first measurement ever occurs, one cannot predict the outcome of the other measurement. Quantum mechanics seems to *require* a frame-*in*dependent notion of simultaneity—something Einstein did away with when he introduced his theories of relativity!

In focusing our attention on simultaneity—for which debate is ongoing as to whether it *is*, after all, a genuine feature of our world—Jammer's book does us a service. Also valuable is the way that it guides readers into the thicket of some current controversies in the foundations of physics. Indeed, one benefit of the book is its vivid depiction of the fits-and-starts quality of scientific inquiry and of the ways empirical evidence, rational

argument and debate aid scientific progress and help guide our choice of which theories to accept. Jammer's discussion shows that the process of scientific understanding and discovery, rather than being incremental and linear, proceeds via leaps and bounds, regresses and progresses, accompanied every step of the way by doubt and questioning.

That said, I would hesitate to recommend the book to those without prior exposure to the material Jammer covers. Although jacket copy for *Concepts of Simultaneity* maintains that the book presents an accessible account, Jammer presupposes more knowledge and understanding on the part of the reader than can reasonably be expected of the uninitiated. A number of concepts and technical terms go unexplained: logical paralogism, Minkowski diagrams, ether theory, light-cone structure, philosophers' A time and B time, and Newton's bucket experiment, to name a few. And long quotations in French go untranslated.

What's more disturbing, a reader with only this volume as a guide might come away with a mistaken impression of what lies behind current debates among physicists and philosophers on the nature of time. For example, Jammer doesn't sufficiently explore the modern geometric view of spacetime, which is the focus of much current work in philosophy of physics, and according to which the question of simultaneity becomes a question about the underlying structure of spacetime.

Surely even in a volume whose primary aim is historical, it would have been valuable to cite considerably more work from the past two decades. Many exciting developments directly related to the main themes of the book have taken place during this time, both in physics itself and in the philosophy of physics. There has been a lot of discussion on the geometric relation between light-cone structure and metric structure in relativity, and what these quantities mean for the reality of simultaneity; on whether current physics can explain our sense that there is an objective distinction between the past and future directions of time; on no-collapse theories of quantum mechanics, such as the "many-worlds" interpretation, which do not require a frame-independent quantity of simultaneity; on recent proposals for Lorentz invariant, or "relativity-friendly," collapse theories of quantum mechanics; and more besides. It is a pity that Jammer ignores these.

Of course, some simplification is needed in any book of just 300

pages on a topic of this magnitude. But Jammer has a tendency toward ungenerous hyperbole: "The relation between 'now' and 'simultaneity' has scarcely ever been discussed," he says. And he occasionally states a controversial thesis as though it were given: "A rigorous definition of simultaneity cannot be obtained without the specification of a physical operational procedure." Although the informed reader may be in a position to overlook these missteps, the neophyte may not be able to recognize them.

One misdirected attempt at simplification, I think, is Jammer's decision to conflate certain distinctions that philosophers have worked hard to make. One is the distinction between our concept of simultaneity (the stated subject of the book) and simultaneity as potentially *a thing out there in the world*. Jammer claims to trace the evolution of our ideas about this thing we call "simultaneity"; yet arguably, our *concept* of simultaneity, and what we *mean* by events being simultaneous, hasn't changed over the centuries. Rather, we've discovered, perhaps, that there is *no* thing in the world corresponding to that concept—just as we've discovered that there is no thing in the world corresponding to our concept of a "luminiferous aether," say. Our concepts might have remained just as they always have been, but we've discovered—to our shock and surprise, dismay and even delight—that reality doesn't neatly map onto our pre-theoretical concepts.

One main view under consideration in the book is the so-called "conventionality thesis." Jammer provides three chapters on the subject, yet he never explicitly states what this thesis is. He seems to take it to be the thesis that simultaneity is "conventional, as opposed to factual." Unfortunately, Jammer fails to note that being conventional is not the same thing as being wholly subjective or non-factual.

Concepts of Simultaneity provides a welcome survey of the development of our views and theories of simultaneity, bringing together sources in history, physics and philosophy. The book covers an impressive array of material. However, there are serious omissions. Because Jammer leaves out some of the most interesting discussions of recent years about the nature of time and simultaneity, I am left unconvinced at the end and remain concerned that this is not, after all, the deepest or most thorough introduction to the subject.