magnetism in France, under the leadership of Curie, Langevin, Weiss and Néel, with a fascinating account of the rise and fall of the "Weiss magneton", but the later developments are only rather summarily dealt with.

A final chapter on the solid-state physics community attempts to monitor, by using statistical analyses, the growth of solid-state physics as a distinct discipline. This seems to me rather a sledgehammer approach. What is perhaps underemphasized is that the community is a loose one, with subcommunities such as those studying low-temperature physics, superconductivity, magnetism, semiconductors and crystallography. These subcommunities hold their own conferences and publish their own journals and in practice have little overlap with each other.

As the subtitle "Chapters from the History of Solid-State Physics" implies, the coverage is only partial and many topics remain to be dealt with. But it is regrettable that there is so little about the important school of solid-state physics in the former Soviet Union, particularly as the advent of *glasnost* in the 1980s should have made it possible to include more. I shall mention only one example. Although Douglas Hartree's contribution to the Hartree–Fock theory is extensively discussed, that of Vladimir Fock, one of the greatest Russian theoreticians, is relegated to a footnote. Other shortcomings indicate inadequate editing and proofreading. The policy of using first names of people when they are first mentioned is not carried through consistently. It grates a little to read "Bertram Brockhouse and A. T. Stewart" as if Alec Stewart was not important enough to deserve a first name. But worse is that some first names are simply wrong. To call Mike Garfunkel Michael (it should be Myron) is perhaps excusable, but Douglas instead of Dermot Roaf and Israel instead of Evgenii Liftshitz is a bit too much. The photographs of leading participants help to provide intimacy between the reader and the scientists, but their value would be enhanced by better captions with more details of time and place. Here too there are mistakes: for instance the captions for Bardeen and Seitz are, I think, interchanged and the picture of Pippard and Kapitza "in Cambridge, early 1960's" was in fact near Moscow in 1957.

This is nevertheless a valuable start to an ambitious project and the book is likely to become an authoritative secondary source for anyone trying to follow up some aspect of the history in depth, so it is to be hoped that there will be a new and enlarged edition in which the shortcomings I have mentioned will be avoided. □

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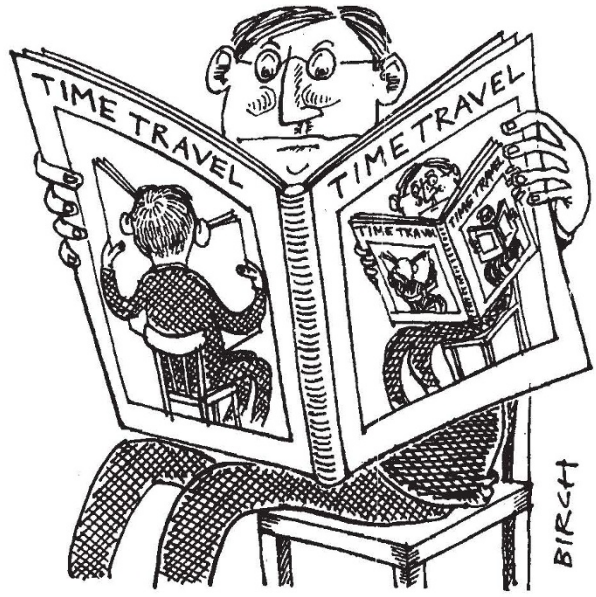
Against the clock

Ian Moss

Time Machines: Time Travel in Physics, Metaphysics, and Science Fiction. By Paul J. Nahin. *AIP: 1993. Pp. 408. $45, £40. (Distributed outside North America by OUP.)*

H. G. WELLS has a marvellous description of time as the "fourth dimension" in his novel *The Time Machine*; it is all the more impressive for being written as long ago as 1895. He had probably been reading *Nature*, for in a July issue of that year there sits an account of an address on the fourth dimension by Simon Newcome, and Wells



mentions the address in his story. This kind of detail fills every paragraph of *Time Machines*.

But what about time travel as more than just a plot device? To retain some respectability we need to talk about 'chronology violation' rather than time travel. In the theory of general relativity, chronology simply means the time ordering of events along lines in spacetime. It is as much a physical concept as force or velocity are physical concepts in newtonian mechanics. (General relativity is Einstein's theory of gravity that seems to fit all of the available data best.)

Work on chronology violation has by necessity taken the form of thought experiments. If one tries to answer the question "what happens if?" by using the theories available at present, then one starts to find inconsistencies that suggest how those theories might have to be modified. If all goes well, this enables one to plan real experiments that test the new theories.

Kurt Gödel, the outstanding mathematician and philosopher, gave the first example of a model universe that was perfectly consistent with general relativity but violated chronology. In Gödel's universe, a spacewoman could fly off in a rocketship and eventually rejoin her own past. (Ordinary English grammar assumes a chronology that is not adequate in this context.) Such a journey through spacetime describes a 'closed timelike loop'.

With the introduction of black holes it becomes possible to find many more examples of closed timelike loops. Instead of being laid down like a sheet, spacetime can have a complicated structure with tubes and folds connecting distant times and places. These often involve new types of matter called 'exotic', which may come in the form of particles that travel faster than light, fields with negative energy or infinitely long strings. Some issues of *Physical Review* are full of exotic matter, but it is still an open question whether exotic matter is necessary.

In many cases, the quantum mechanical energy of the vacuum seems to prevent causality violation, leading Stephen Hawking to propose a 'chronology protection conjecture'. If this conjecture is false then there would be causality violation paradoxes. An example is the grandfather paradox: what would happen if a time-traveller went back in time and tried to kill his own grandfather? There is also the causal loop paradox: a time-traveller goes back in time to tell his younger self how to build a time machine. Where does the information about how to build a time machine come from? These paradoxes are now studied in mathematical physics and no longer seem to be the obstacles that they were once thought to be.

The research that has gone into this book is impressive. The author has made a good selection of ideas from the scientific literature on spacetime, causality violation and time-travel paradoxes, and they are presented at a popular level, with science-fiction plots running in parallel. Often the fictional ideas came first. Bob Olsen's doggerel, for example, which appeared in the July 1934 issue of *Amazing Stories*, is as pertinent today as it was then:

> Let's hope, in planning new inventions,
> They'll give us cars with four dimensions.
> When searching for a parking place
> We sure could use some hyperspace! □

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