there is chapter 7, "The Cigars and Brandy: Social Behavior, Culture and Thought," which raises the issue: Would machines behave like humans, individually and collectively? Finally, there is an "Afterwards," with a summary and bibliography on the development of artificial intelligence since the imagined Cambridge dinner.

Unfortunately, Casti puts into his participants' mouths arguments they would never have made themselves. There is sloppy physics for Schrödinger—for example; "Axiom 1: Electricity and Magnetism are forces." Tautological self-contradictory progressions and non sequiturs are attributed to Wittgenstein, who offers apparently formal "proofs" in which one of the axioms asserted is self-evidently the contention to be proved—for instance, that rule-driven processes can never lead to "understanding": "Axiom 1: Programs are purely syntactic objects. Axiom 2: Human minds have semantic content. Axiom 3: No amount of syntax can generate semantics. Conclusion: Programs are neither necessary nor sufficient for minds." (I am confident in my assessment of the Schrödinger section, less so for Wittgenstein.)

What's more, fundamental points that were well known at the time, and that these luminary intellects would certainly have made, are missed. For example, none of Casti's diners mentions that a computer's program is expressed in the same manner as its data. This makes it possible to transform the programs as well as the data, certainly an important aspect in discussing computer learning. Nor do the discussants point out, in spite of its obvious relevance to the discussion of rule-based versus social-based languages, that people do learn each other's languages without verbal explanation of the rules; effective working rules are inferred from observation of behavior.

Of the five dinner celebrants, only Turing seems coherent and consistent. Wittgenstein is continually flipping back and forth between, for example, the assertion that thought requires words (language) and the counter-assertion that thought is independent of words. The others often seem to follow his sudden, unexplained reversals. It is hard not to conclude that the dinner party is a setup to display Casti's favorite diner—Turing.

Among the points upon which the five conversationalists seem to reach consensus are: 1) A machine must have a complete set of sensory organs to be said to think; 2) for machines to be said to think they must belong to a population of similar machines so as to have the "culture" required for language and, hence, thought; and 3) somehow, a "thinking machine," implies a "living machine," which then requires the consideration of its "personhood."

To me, these are non sequiturs. There are many like them in the book, as well as numerous missed opportunities to make pungent, clarifying arguments on either side of the issue: Turing makes some pragmatic, testable arguments that machines can think; Wittgenstein simply asserts the contrary! And yet, the book is informative and fun to read. Savor or taste it; participate deeply in the conversation to find your own set of flaws and weaknesses of arguments, or skim it lightly just to enjoy the conceit. Perhaps Casti is hinting that the five dining companions, in spite of their luminous intellectual reputations, are mere mortals, prone to error and shortcomings and in need of replacement by thinking machines. But would the machines enjoy the meal?

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Introduction to Geomagnetic Fields

Wallace H. Campbell
Cambridge U. P., New York, 1997. 290 pp. $69.95 hc
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The plural "fields" in the title of Wallace Campbell's *Introduction to Geomagnetic Fields* drew my attention, and I was not disappointed when I later delved into this compact introductory text. Campbell has attempted to cover three major types of Earth's magnetic fields: the internal or main field that originates in the fluid core; the "quiet time" or regular daily perturbations in Earth's magnetic field, originating in the upper atmospheric currents; and the geomagnetic storms, solar flares and other occasional sharp changes in the field whose causes lie in an active Sun.

The magnitudes of geomagnetic fields have a dynamic range of 16:1. While the main field can have a magnitude of around 60 000 nanotesla (Campbell uses "gamma" instead of nanotesla), the solar quiet (Sq) diurnal variations can be as low as 20 nT, while geomagnetic storms can reach 1000 nT. Given this wide range in magnitudes, sources and variability, it would be difficult to write a text, not to speak of an introductory text, that would cover the origin and behavior of all the components of geomagnetic fields with any degree of felicity.

Campbell, a researcher with a long and distinguished record of research in ionospheric currents and geomagnetic storms, has succeeded in covering the last two topics of the three mentioned above, and he has made what amounts to an honorable stab at the first. This is not a damning criticism, because it is rare to find an introductory text on magnetic storms and quiet-day variations free of the daunting derivations of equations that Campbell calls "mathematical gymnastics." These two research fields cover 110 of the total of 247 pages in the five chapters of the book. Each chapter has a wealth of figures and a helpful summary at the end. The references to work published after 1990 tend to be few and far between.

Chapters 2 and 3 present a very readable and simplified description of the behavior of quiet-field (Sq) ionospheric current systems, their spherical harmonic analyses and the plethora of solar–terrestrial effects of an active Sun: sunspots, flares, mass ejections, storms and substorms. For a main-field enthusiast such as myself, these two chapters were a very helpful primer for more advanced research papers on these topics, and I know that my students in main-field geomagnetism will also benefit from my broadened horizon.

I wish I could be as enthusiastic about chapter 1, on the main field. The 61 pages in this chapter provide a good description of the components of the dipole field, Carl Friederich Gauss's spherical harmonic analysis of the global field and the International Geomagnetic Reference Field descriptions up to the year 1995 and gauss coefficients up to degree and order 6. But the origin of the field (dynamo theory) and its geological time variations (paleomagnetism) are barely touched upon. Even when the reader is referred to other textbooks for further details, the summary information given is fairly old. For example, Campbell not only fails to mention the pathbreaking three-dimensional numerical modeling of the geodynamo by Gary A. Glatzmaier and Paul H. Roberts in 1995, but also ignores the kinematic dynamo models of the 1950s by Edward C. Bullard and by Walter M. Elsasser. I was surprised to find that these two stalwarts of geomagnetism were not even listed in the references of a book published last year. (Nor did I expect to see "quadrupole" and "octupole" spelled as "quadr*a*pole" and "oct*a*pole!")

Let me end the review by citing some of the book's strengths that will make it attractive to beginning graduate students, geomagnetic observatory technicians and others new to geomagnetism and especially to the non-main field that is generated outside Earth's fluid core. Such "goodies" include a large list of computer programs for data handling and manipulation and addresses of the sources for such utility programs and an appendix that briefly introduces the student reader to the mysteries of logarithm, trigonometry, complex numbers and vector calculus. Also noteworthy is the list of Campbell's technical reports on his research, cited in the acknowledgements.

Overall, the personal style of Campbell's writing, his concern for the reader being "on the same page" as he is and his obvious enthusiasm for the subject make the book a good introduction for the nonspecialist. For the student with a stronger background in physics and mathematics, Wilfred Dudley Parkinson's *Introduction to Geomagnetism* (Scottish Academic Press, 1983) is still a better bet.

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The Geometry of Physics: An Introduction

Theodore Frankel
Cambridge U. P., New York, 1997. 654 pp. $95.00 hc
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From the earliest days of science, there has been a love affair between geometry and physics. In fact, there were times when the two disciplines were so intertwined that it was hard to tell them apart. Newtonian mechanics went hand in hand with Descartes's analytic geometry, and many of the founders of modern differential geometry, such as Carl Friedrich Gauss, Bernhard Riemann, Felix Klein, Sophus Lie and Henri Poincaré, would qualify as mathematical physicists in their own right.

With the birth of the two theories of relativity (in 1905 and 1915, respectively), thanks to such people as Albert Einstein (with some help from Marcel Grossmann and Hermann Minkowski), Hermann Weyl, David Hilbert and many others, tensors slowly became a household word among theoretical physicists. Theoretical physicists became masters of "index gymnastics," while neglecting another important line of development: the use of exterior differential forms, developed mainly by Elie Cartan and his school and carried forth by the younger generation of French, Swiss, Chinese and American mathematicians.

Though the monumental treatise *Gravitation* by Charles Misner, Kip Thorne and John Archibald Wheeler (W. H. Freeman, 1973) made extensive use of differential forms, it took a long time for other textbooks on relativity to follow suit. The situation changed somewhat in the late 1960s and early 1970s, when a number of people (such as Elihu Lubkin, Robert Hermann, Andrzej Trautman and I) noticed that the language of connections in fiber bundles was the natural setting for gauge theories (of both the abelian and nonabelian kind).

The discovery of instantons and their interpretation in terms of Chern classes, and the use of the Atiyah–Singer index theorem for "instanton counting," finally brought the importance of modern differential geometry to the attention of the wider theoretical physics community. Differential geometry methods in physics have gained a new impetus through the popularity of string theories and their "moduli spaces" and the widened interest in relativistic gravitation and cosmology. A number of new textbooks and monographs—by Ralph Abraham, Jerrold Marsden and Tudor Ratiu (*Manifolds, Tensor Analysis, and Applications*, Addison-Wesley, 1983), by Yvonne Choquet-Bruhat, Cécile de Witt-Morette and Margaret Dillard-Bleick (*Analysis, Manifolds and Physics*, North-Holland, 1982 and later editions); by Bernard Schutz (*Geometrical Methods of Mathematical Physics*, Cambridge U. P., 1980), by Walter Thirring (*A Course in Mathematical Physics Vol. I, II*, Springer-Wien, 1978, 1979 and later editions) and several others—appeared, and some have been used to teach graduate students.

The publication of *The Geometry of Physics* by Theodore Frankel fills a gap in the available literature in that it provides a highly readable and enjoyable exposition of a variety of differential geometric methods that are useful in physics. The book could be used as a text in a graduate course or as a reference for working theoretical and mathematical physicists. The author, a professor emeritus at the University of California, San Diego, is well known for his contributions to general relativity, the application of differential forms to electromagnetism and continuum mechanics and waves on manifolds. He is the author of *Gravitational Curvature* (Freeman, 1979).

Frankel's book is very well written, avoids the dry definition–theorem–proof approach and introduces nontrivial topics early, keeping the interest of the reader alive. Thus, the concept of vector bundle appears as early as page 48, and even an advanced reader will find interesting topics scattered