long run, as low-voltage direct-current transmission and distribution take over in emerging industrial regions globally. Here, however, Livingston makes a cogent observation on materials and technologies in general: "a better figure of merit than energy product is *energy product per dollar*". Harvard, he says, did not teach him this as a graduate student, and nor did it me during my time at that illustrious institution. It is still probably the case.

My few criticisms aside, this is a smashing book. I wish I had written it and I want to write one like it some day. I wish something similar had been around when I was in high school. In an era of

unfortunate public distrust and misunderstanding of the scientific method, I wish there were more science books for the general population written with so engaging an approach. Finally, in the spirit in which the author began his book, and I this review, I wish the 'natural magic of magnets' was used more often to introduce science to children in our pre-schools. It isn't, not in my neck of the woods, and it's a shame. As the Yanks say, "There oughta be a law...". □

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Changing music of the spheres

Paul Murdin

Feynman's Lost Lecture: The Motion of Planets Around the Sun. By David L. Goodstein and Judith R. Goodstein. Norton: 1996. Pp. 224. \$35, £16.99. To be published in the UK by Jonathan Cape in July.

RICHARD Feynman, renowned for his sophisticated course of physics lectures at the California Institute of Technology in the early 1960s, also gave guest lectures. Records of only five of them survive. "The Motion of the Planets Around the Sun", the only publishable one, was discovered by Judith Goodstein, the archivist at Caltech, and has now been released on compact disc with notes edited

by the physicist David Goodstein.

The theme of the lecture is Kepler's first law (1609), which states that the orbits of the planets are conic sections or ellipses. In 1684, Isaac Newton explained to Edmund Halley that simple principles in dynamics and a central inverse-square force were sufficient to give planetary orbits as described by Kepler's three empirical laws, including his second (the radius-vector from the Sun to a planet sweeps out equal areas in equal times) and his third (the 'harmonic law' — the period of a planet is proportional to the three-halves power of its mean distance from the Sun). The second law represents the conservation of angular momentum, the third law comes from the inverse-square law and the first law follows from the other two.

Newton's explanation is a virtuoso piece to perform. Like a musical performance transcribed for modern instruments, Feynman's is, however, not quite a repeat of the original tune, and it has an original cadenza, placed, unusually, at the end.

In *Principia Mathematica* (1687), Newton relied heavily on the properties of conic sections. Feynman follows Newton's geometric methods but uses nothing more advanced than congruent triangles. At first he follows Newton exactly, but then he diverges. "I found I couldn't follow [Newton's proof] very well, because it involves so many properties of conic sections. So I cooked up

another one", he says. Feynman's cooking, presumably independently, follows a recipe published by James Clerk Maxwell, who in turn attributed it to Sir William Hamilton.

Feynman's Lost Lecture goes over some well-trodden history, from Copernicus through Newton to Einstein, and contains reminiscences about Feynman, including the rediscovery of the lecture. There is a transcript of the lecture itself, as well as a compact-disc recording of Feynman delivering it to the Caltech freshman class of 1964. The core of the book is a step-by-step account of his argument that will be accessible to any science student, from sixth-form (high-school) level upwards.

The closing minutes of the lecture display Feynman's gift for lateral thinking. Apparently with time to spare, Feynman turns to Rutherford's experiment demonstrating the small size of the atomic nucleus by alpha-particle scattering. This is a problem of electrostatic repulsion, not of gravity, but the force is a centrally acting inverse-square law and the alpha particles have Keplerian motion. All the Newtonian arguments apply. With them, Feynman derives the probability of the deflection angle of an alpha particle. He uses a treatment by U. and L. Fano from a basic atomic physics textbook of 1959; this seems to have been what gave Feynman the idea of this enjoyable lecture in the first place. □

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A honeyed society

Ross H. Crozier

The Wisdom of the Hive: The Social Physiology of Honey Bee Colonies. By Thomas D. Seeley. Harvard University Press: 1996. Pp. 295. \$49.95, £31.50.

That which is not good for the swarm, neither is it good for the bee.
Marcus Aurelius

EDWARD O. Wilson, commenting on the work of Karl von Frisch, once wrote that the honeybee is like a magic well to which one can always return for something new and refreshing in the study of social behaviour. The species repays its acolytes by providing all sorts of avenues of investigation not only into selection of a eusocial species (and an economically important and semi-domesticated one at that), but also into the social integration of many individuals to form a smoothly functioning whole. Thomas Seeley stresses the second aspect, providing a largely personal

Feynman's argument will be accessible to any science student from sixth-form level upwards.