Feynman's Lost Lecture

The Motion of the Planets Around the Sun

Shailesh Shirali

The Motion of Planets Around the Sun
David L Goodstein and Judith R Goodstein
Published by Vintage
pp.191,1997, £4.50 (paperback)

Everyone knows about the three-volume *Feynman Lectures In Physics*, which surely is one of the great contributions of this century to science literature. The book under review, written by friends and colleagues of Feynman's, documents one of the lesser known stories associated with the *Lectures*: how five of them got omitted from the published version, and one of them, delivered in CalTech in March 1964 and titled 'The Motion of the Planets Around the Sun', was rescued from oblivion in 1994 by the authors, using only the audio tape of the lecture and some notes that Feynman had prepared fortunately containing a few sketches.

The authors have produced a very valuable book. Its value lies not only in the insight it provides into the style of teaching and working of a very great physicist (for instance, it reveals the great care that Feynman took over his lectures; a phrase casually thrown in during a lecture may in fact have been agonised over for hours before the lecture), but it does a wonderful job of capturing and laying out on a broad canvas the historical setting behind the subject matter of the lecture.

Chapter 1, titled *From Copernicus To Newton*, provides a quick tour of celestial mechanics as it advanced during the times of Copernicus, Brahe, Kepler, Galileo and Newton. Wonderful discoveries were made: the Copernican model of the solar system; Kepler's three laws of planetary motion, found after two decades of toil; Galileo's observations: (a) the natural state of an object in horizontal motion is to keep moving horizontally, forever and at constant speed (this was later refined and formalised by Newton as a law of motion), and (b) the path followed by a projectile near the earth's surface is a parabola; and finally, the extraordinary contributions of Isaac Newton – the law of gravitation, invention of the calculus, formalisation of the three laws of motion, and his extraordinary treatise, *Principia Mathematica*, in which he does nothing less than lay out the system of the world. The story is an inspiring one, and the authors tell it with humour and precision.

Following this chapter is a biographical one titled *Feynman: A Reminiscence*, which provides a thumb-nail sketch of his life and work. The story is told with affection and humour. Readers who have gone through Gleick's book '*Genius*' and Feynman's own bestsellers, *Surely You're Joking, Mr. Feynman!* and *What Do You Care What Other People Think?*, may not find much that is new, but the chapter does provide fresh insights into Feynman's personality. The description of the 'only private verbal exchange' that occurred between Einstein and him is amusing. (I will not spoil the reader's fun by describing it here.) A rather touching incident describes him and Goodstein (one of the authors of the book under review) attempting to track down an error in one of their joint papers. Just a few days earlier, Feynman had been diagnosed as having stomach cancer and was to go in for surgery. Nevertheless, he got to work

"*. with unflagging energy on an unimportant problem in two-dimensional elastic theory. The problem proved intractable. At 6 P.M., we declared the situation hopeless and went our separate ways. Two hours later he called me up at home. He had the answer! He had not been able to stop working, he told me excitedly, and had finally tracked it down. He dictated the solution to me. Four days before entering the hospital for his first cancer operation, Richard Feynman was bursting with joy. . . .*"

The high personal regard and affection which Goodstein feels for Feynman are in evidence all through the chapter.

The next two chapters are about the actual lecture which Feynman gave on the subject of planetary motion. Why did he decide to give such a lecture? When Newton presented a proof of the law of ellipses in the *Principia*, he used the language of classical geometry which others of his time would understand Feynman was sufficiently intrigued by the proof to want to find one for himself. (This was typical of him). He says in his lecture, "... It is not easy to use the geometrical method to discover things, but the elegance of the demonstrations after the discoveries are made is really very great. The power of the analytic method is that it is much easier to discover things than to prove things. But not in any degree of elegance." One must remark here that personal and aesthetic elements inevitably enter into any discussion concerning proof. Given a proposition, which of several proofs available should one consider the 'best'? One may use the most powerful techniques available at hand and obtain the desired result with comparatively little effort. Sometimes however, one may seek a proof using the simplest tools. This is likely to be longer and more difficult to find and understand but there is a certain satisfaction in being able to find one. Dichotomies of this kind often arise in plane geometry, where any valid proposition can (in principle) be proved using analytic geometry or trigonometry. Such proofs can be quite unappealing, not subtle and incisive. Another striking example is provided by the prime number theorem, first proved in the 1890's using the machinery of complex variables. An elementary later proof avoids entirely the heavy machinery used in the earlier proof. (It is another matter that the 'elementary' proof is more difficult to understand).

Chapter 4 gives the lecture in verbatim form (including grammatical errors!), while Chapter 3 gives a very detailed annotated form of the lecture. It seems that the authors have written the book for a very general audience, taking nothing for granted. Chapter 3 alone occupies more than 80 pages with some 150 illustrations! Unfortunately this gets to be quite tedious – readers who are familiar with the subject matter will probably feel the urge to race through the chapter or skip it altogether. The authors take great pains to establish the propositions used by

Feynman; for instance the fact that for an ellipse with foci at S and H, the locus of the image of H under reflection in all possible tangents to the ellipse is a circle centred at S. This fact is used by Feynman in an elegant way to show that an ellipse is one possible orbit of a planet. The crucial insight that he hits upon is the fact that as the planet moves around the sun, the velocity vector moves in a circle. (Well before Feynman, Maxwell and Hamilton had found this a century earlier, see also T Padmanabhan, *Resonance*. Vol.2. No.3. 34, 1996).This is forced by the inverse square law of gravitation, and essential to the final part of Feynman's proof.

The authors could perhaps have included compact proofs of some propositions in an appendix. For instance the vector proof mentioned above is more convincing and shorter than the geometric one of Feynman. Some arguments offered by the authors seem unnecesarily involved; for instance, the footnote on page 115, which attempts to explain why for points A, B, C on an orbit, with the sun at S, if the central angles ASB and BSC are equal and small, then the ratio of areas of the sectors ASB and BSC is roughly $AS^2 : BS^2$. A proof using the fact familiar to most readers that the area of a sector of a circle with radius r and central angle θ is proportional to both r^2 and θ may be more convincing.

Feynman confesses that he was unable to follow Newton's geometrical arguments at one point, as they depend heavily on obscure properties of the conic sections; so he set himself the task of devising his own proof (and did so). The authors of the book found themselves in a similar predicament, as they had only an audiotape and some sketches to go by. After great effort they succeeded in reconstructing Feynman's proof. As it happened, I found myself similarly placed with regard to the authors' version of the proof, and had to do a fair amount of work before I could feel confident about the argument! Readers will probably report similar experiences. (Perhaps this says more about the problem than the various proofs; but I still feel that the authors' exposition could be improved.)

Towards the end of the lecture Feynman shows how the same method provides an explanation for the behaviour of an α-particle beam when fired at a heavy nucleus. The difference between this situation and the preceding one is that the forces are repulsive rather than attractive. It turns out that under a model in which all the positive charge is concentrated into an exceedingly tiny space, the spatial distribution of the reflected beam can be predicted precisely, and this matches closely with the observed facts. This discovery was pivotal in the acceptance of the nuclear model, and this led in turn to the Bohr model of the atom.

The story is stirring , and the authors have done a good job of conveying its flavour and drama. The book may at times tax the lay reader, but on the whole it has been written with skill. Despite its flaws, I feel that it is a 'must read' for anyone with an interest in physics, and indeed for all undergraduates in physics and mathematics.

Shailesh Shirali, Rishi Valley School, Chittoor District, Rishi Valley 517 352, Andhra Pradesh, India.