
Red and Green Lights to Insight: A Review

Two Recent Books from Thomas H. Lee

By David Jefferies

INTRODUCTION

Whilst there are many established classic texts in the general area of RF, microwave, and antenna systems, readers of *antenneX* magazine may, like me, always be on the lookout for notable new books which have something to offer the reader which is not available elsewhere in the Public Domain. One might think that this is rather difficult, given the maturity of the discipline, and so new books that stand out from the generality of those on offer don't come along very often. This month seems to be an appropriate time to review two books by the Stanford University professor Thomas H Lee, both published by Cambridge University Press. Your reviewer hopes to make a case for the accession of these books to the library of keen amateurs, as well as RF professionals.

Both these books bear the date 2004. The more recent is red, "Planar Microwave Engineering" and the slightly older one is green, "The Design of CMOS Radio-Frequency Integrated Circuits - 2nd edition". They are produced to similar formats: 862 and 797 pages respectively, very similar in size and appearance (see photos of covers) and written to a similar formula. There is a certain amount of overlap in the topics covered but it is not the purpose of this review to perform a detailed "compare and contrast exercise", but rather to direct the reader to the accessible information contained within. One might at first sight think that these titles sound rather unpromising for the Ham interested primarily in HF systems from 1-30 MHz; your reviewer hopes to uncover subjects presented in an appetizing manner which are perennials in Ham-community discussions.

The bibliographic details and chapter headings are given here together for comparison purposes.

First, the red book:

Planar Microwave Engineering – A Practical Guide to Theory, Measurements, and Circuits

by Thomas H Lee (Stanford University)

Cambridge University Press UK 2004

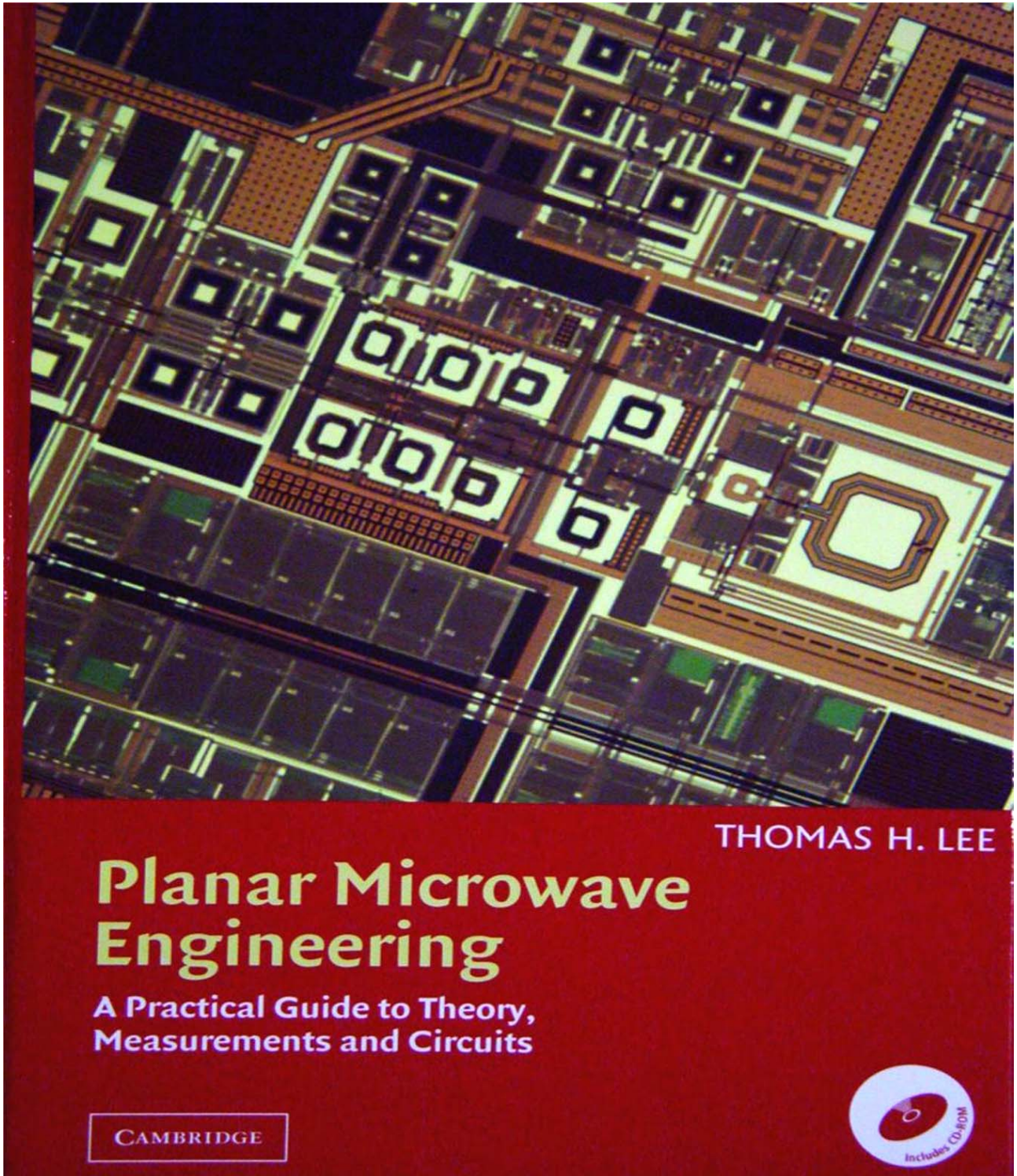
ISBN 0-521-83526-7

xviii + 862 pp and includes CD-ROM

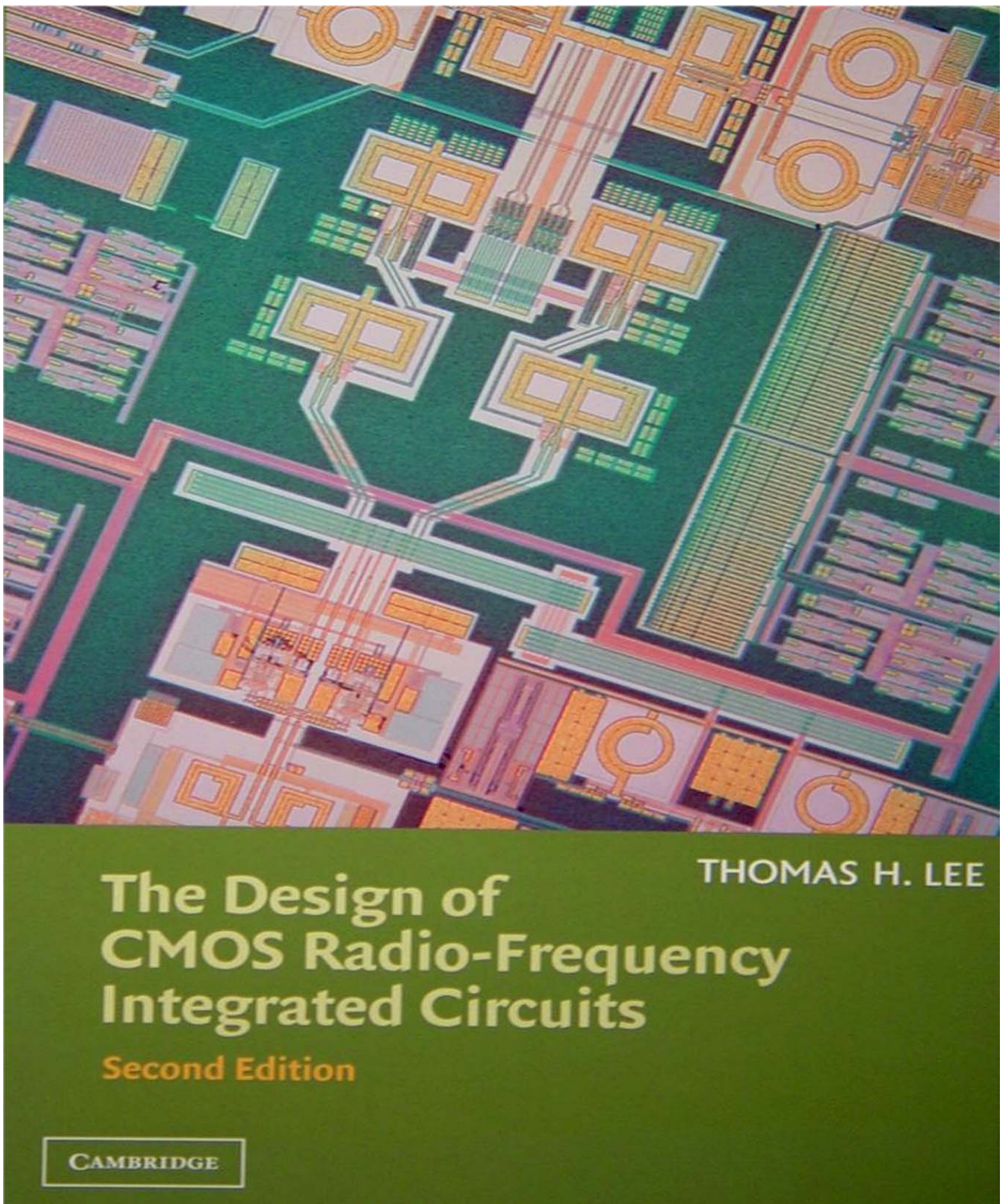
Preface

- (1) A microhistory of microwave technology
- (2) Introduction to RF and microwave circuits
- (3) The SMITH chart and s-parameters
- (4) Impedance matching
- (5) Connectors, cables and waveguides
- (6) Passive components
- (7) Microstrip, stripline and planar passive elements
- (8) Impedance measurement
- (9) Microwave diodes
- (10) Mixers
- (11) Transistors
- (12) Amplifiers
- (13) LNA design
- (14) Noise figure measurement
- (15) Oscillators
- (16) Synthesizers
- (17) Oscillator phase noise

- (18) Measurement of phase noise
 - (19) Sampling oscilloscopes, spectrum analyzers, and probes
 - (20) RF power amplifiers
 - (21) Antennas
 - (22) Lumped filters
 - (23) Microstrip filters
- Index



Now for the other book – the green one:



The Design of CMOS Radio-Frequency Integrated Circuits, Second edition
by Thomas H Lee (Stanford University)
Cambridge University Press (UK) 2004
(First edition 1998)
ISBN 0-521-83539-9
xviii + 797 pp

Preface to the second edition
Preface to the first edition
(1) A nonlinear history of radio
(2) Overview of wireless principles
(3) Passive RLC networks
(4) Characteristics of passive IC components
(5) A review of MOS device physics
(6) Distributed systems
(7) The SMITH chart and s-parameters
(8) Bandwidth estimation techniques
(9) High frequency amplifier design
(10) Voltage references and biasing
(11) Noise
(12) LNA design
(13) Mixers
(14) Feedback systems
(15) RF Power amplifiers
(16) Phase-locked loops
(17) Oscillators and synthesizers
(18) Phase noise
(19) Architectures
(20) RF circuits through the ages.
Index

The first chapters to mention from these books are the Historical chapters; “A microhistory of microwave technology” (Red, 1), “A nonlinear history of radio” (Green, 1), and “RF circuits through the ages” (Green, 20). There is a certain amount of repeated material here (even Handel and Bach recycled material) but when you have read it in one book, its presence in the other in a different context gives one the security that comes from recognition. There is also a historical overview of cellphone technology in “Overview of wireless principles” (Green, 2) which serves to remind us (if we are over 50) just how far we have come in wireless engineering in the second half of the 20th century. There is a common section: “who really invented radio?” (the author says this is an intentionally provocative question) which mentions Loomis, Ward, Hertz, Lodge, Dolbear, Popov, Tesla, and Marconi, and you may make your preferences based on nationality or cultural proclivity as well as technical issues. The chapter (Green, 20) on RF circuits has an extensive discussion of Armstrong and superregeneration. For those people happy with valves – vacuum tubes – the books have a healthy admixture of vacuum tube technology.

ABOUT ANTENNAS

Readers of *antenneX* will then be interested in the chapter on antennas (Red, 21) of which there are 34 pages. It is worth quoting what Professor Lee says about these 34 pages. “..the main goals here are (a) to develop intuitive insights that are infrequently provided by....rigorous mathematical treatments found in some texts, and (b) to supplement the brief explanations commonly offered by many “how-to” books....be forewarned that we will sometimes (actually, often) sacrifice some rigor in favor of the development of design insight. In fact, there may be so much handwaving that you will occasionally need a windbreaker. You will not see a single integral involving the magnetic

vector potential, for example.” This mellifluous quotation sets the tone of the entire 1600 pages of these two textbooks, and it goes a long way to explaining why your reviewer likes them so much.

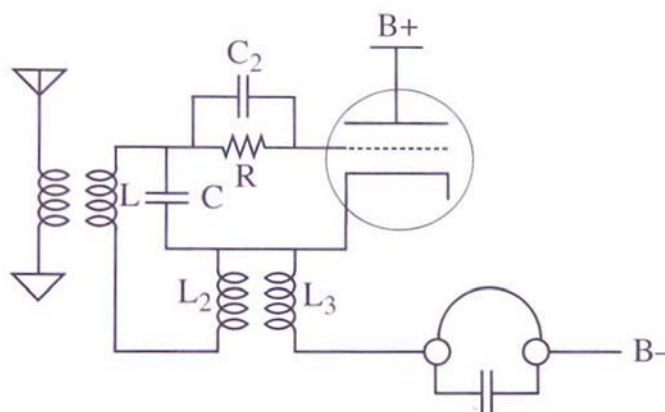


FIGURE 20.2. First regenerative amplifier (adapted from Armstrong).

So, let us digress a moment to see what Lee has to say about antennas that we might find novel, interesting, and instructive. “A clear understanding of a dipole's limitations explains why certain modifications, such as the addition of 'capacity hats' or loading coils, can greatly improve the radiation properties of short dipoles. As will be shown, this same understanding reveals a relationship among normalized length, efficiency, and achievable bandwidth that is reminiscent of the gain-bandwidth trade-offs found in many amplifiers.”.....”To develop a unified viewpoint that explains when a wire is a wire and when it's an antenna, it is critically important to discard the mental imagery – of electricity-as-a-fluid traveling down wires as pipes – that is consciously implanted in students before and during their undergraduate education. Instead, understand that ideal wires, strictly speaking, *do not carry electromagnetic energy at all*. Many (perhaps most) students and engineers, to say nothing of lay people, find this statement somewhat controversial.”... He goes on to appeal to Poynting's theorem, and demonstrates that the Poynting vector $\mathbf{E} \times \mathbf{H}$ is identically zero *inside* a conducting wire because the electric field is there everywhere zero. The propagating energy is therefore entirely confined to the region *outside* the wire. “...many students....have a tough time when this particular necessary consequence is expressed in words, for it seems to defy common sense and ordinary experience (I get a shock only when I *touch* the wire)’”.

Lee suggests that you retain the idea of conductors as guides of electromagnetic energy rather than as conduits.

Perhaps this limited extract will convey the flavor of these books rather better than reviewer's hype can achieve. There follows a section (21.3) called “The nature of radiation”. Another quote....”more than a few students have caught on to the fact that electrodynamic equations...are a devious invention calculated to torment hapless undergraduates...” and there follows a couple of pages of verbal description of why an antenna of length about a quarter-wavelength must radiate. At this point your reviewer leaves the quotation game, and at least a visit to a library is indicated.

Being a book primarily about “planar” structures, there is a nice introduction to planar microstrip patch antennas. And the practical methods needed to hack such structures are not forgotten. For example, “..one convenient method for trimming such an inset patch for prototyping purposes is first to use a deeper-than-normal inset. Then, upwards impedance adjustments are easily effected by placing a shorting strip across some portion of the inset.....this particular method avoids the need for precise cutting and also facilitates multiple iterations. Soldering (and unsoldering) a piece of copper foil tape is much easier than gouging out segments of copper cladding”.

In a conventional thriller it is possible to skip to the last page to see who did it. Thus “we've seen that radiation is primarily the result of the finite propagation speed of light. The need for sufficient phase shift to provide a reasonably high radiation resistance explains why real antennas are a reasonable fraction of a wavelength in extent, at minimum.”

Encouraged by a read of the chapter on antennas, about which we may feel we have views and insights, we may explore further in the books. In the Planar Microwave Engineering book one of the first things which caught your reviewer's eye was the chapter (Red, 5) entitled “connectors, cables, and waveguides”. One might be a bit surprised to find a chapter on these three dimensional structures in a book primarily about 2-d circuits and engineering. These devices are described in terms of the higher order modes (“moding”) that can exist as the frequency is increased. There is an extended discussion of the various kinds of coax connector, on the tolerance of their parts, and of the desirability of using a torque wrench to tighten them to prevent cumulative damage. There is a section entitled “why coax?” (shielding to suppress radiation) and the natural progression to waveguide (hollow pipe) to reduce loss at higher frequencies. There is a discussion of overmoded waveguide and a description of why the TE_{0,n} modes in circular guide are intrinsically very much lower loss than the generality of modes in other guides. (The radial E field is zero on the inner guide surface). “Until the development of optical fiber, circular waveguide was the lowest-loss way to convey a signal from one point to another”. There is a table (5.1 on page 121) giving the loss per 30 meters for common coaxial cable types from 100MHz to 5GHz.

MAGNETICALLY COUPLED CONDUCTORS

In the chapter on passive components (Red 6) one interesting snippet which caught my eye concerned the inadvertent mutual inductance and coupling between adjacent tracks on a printed circuit. Section 6.6 is called “magnetically coupled conductors” - a topic certainly of interest to *antenneX* readers – and we learn that for tracks 10mm long with spacing 1mm between them, as one might find running in to an IC on a circuit board, the self inductance of each wire in isolation is about 10nH whereas the mutual inductance is 4nH, a coupling coefficient of 40%. “Furthermore, the logarithmic dependence of M on spacing means that the coupling decreases slowly with distance, so the coupling between even non-adjacent pins can be troubling.” This leads in to a section (Red, 6.6.3) on broadband transmission line transformers. “We've already examined conventional transformers and alluded to the limited bandwidth arising from winding capacitance and leakage inductance. We now briefly discuss *transmission line* transformers which (because of their unique construction) suffer much less from these limitations. permitting operation over unusually large bandwidths”, and then there follows a reference to a hard-to-obtain article by G Guanella in the *Brown-Boverie Review* 327-9 Sept 1944, which describes a class of “balun” with a conducting path from input to output and nominally zero magnetic flux in the transformer core. The advantage of absorbing the winding capacitance into a transmission line description of the inductors accounts for its enhanced bandwidth. A further reference giving more detail is to Jerry Sevick in “*Transmission Line Transformers*”, edition 2, ARRL, 1990.

The coupling between adjacent conductors is treated in greater detail in the subsequent chapter (Red, 7) microstrip, stripline, and planar passive elements, with section 7.6 on combiners, splitters, and couplers. Although it might be thought that these small scale specialized microwave components have little applicability to HF ham antenna practice, the principles of coupling between adjacent conductors are universal and scale with wavelength and frequency.

One of the interesting formulas quoted (Red, page 140) is for the inductance (in Henries) of a current sheet, or, as it might be, a ground plane. Suppose the sheet is l meters long and w meters wide then the inductance is approximately $(2E-7)l(0.5 \ln(2l/w) + w/3l)$ which is about 136 w nanoHenries for a square sheet of side w meters or an inductive impedance of 16 ohms for a 5 meter square ground plane at 80 meters.

CONCLUSION

Well, perhaps your reviewer has now produced sufficient snippets to whet the appetite of the reader. In the other book (Green) there is much more information which is of general utility outside the specialism suggested by the title's reference to CMOS RF integrated circuits. In both books there are good introductions to the SMITH chart and to matching problems. They are excellent books to have on one's shelf to provide pedagogical ideas for teaching the fundamentals of RF systems to starting students, and there is so much practical detail in them that it is reasonable to assume that they will also be of use and interest to the keen ham.

Perhaps it is best to conclude with the current price of these books, as quoted by the publishers on 10th November 2004. The site is <http://www.cambridge.org/> and the price for each book is 45 pounds sterling. At that price they are both bargains. -30-



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