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Book Review

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Modern Astrodynamics: Fundamentals and Perturbation Methods

Victor R. Bond and Mark C. Allman, Princeton University Press, Princeton, NJ, 1996, 250 pp., $35.00, ISBN 0-691-04459-7

According to the Preface, this book is based on graduate courses taught at the University of Houston–Clear Lake over many years to employees of NASA Johnson Space Center and its supporting aerospace contractors. The stated intent of the book is to be both fundamental and applied, and it generally succeeds in this goal. It is one of several recent books on astrodynamics.[1–5]

The book is divided into two main sections: Fundamentals and Perturbations, of approximately equal length with a total of 11 chapters. One drawback of the book as a textbook is that there are no problems at the ends of the chapters. There are, however, eight "algorithms" showing computational procedures for some basic problems and a few numerical examples.

The index is helpful but incomplete. One finds "mean motion" but not "period." The formula for elliptic orbit period is somewhat buried in Section 3.3, Kepler's Third Law, several pages before mean motion is defined, and no connection is made between mean motion and period.

The reader may be somewhat distracted by some nonstandard notation. Total energy is denoted by h, the angular momentum vector by $\boldsymbol{c}$, and the eccentricity vector by $\boldsymbol{P}$. Otherwise, the notation is fairly standard.

Following a discussion of Newton's laws in Chapter 2, a standard definition of an inertial reference frame is given as a frame in which Newton's laws are valid. But in Sec. 2.4 an inertial frame for the two-body problem is defined with the origin at one of the masses. This is an inertial frame only if that mass is infinite (i.e., unaccelerated by the other mass). If one applies Newton's second law in this frame, one does not obtain the correct equation of motion for the general case that contains the gravitational constant $m = G(m_1 + m_2)$. Fortunately, at this point in the text, the correct equation of motion has already been derived and only a (correct) discussion of the integrals of the two-body problem remains.

In Sec. 3.3, Kepler's third law is verified by showing that the square of the period of a planet orbit is proportional to the cube of its semimajor axis. But the proportionality factor contains the gravitational parameter m mentioned above. Thus each planet has a slightly different proportionality factor and Kepler's third law is only approximately correct. In the section that follows (3.3.1), this fact is explicitly used to determine the ratio of the mass of a planet to the mass of the sun.

The derivation of Kepler's equation is fairly complete but appears in three different locations: Chapter 4 for elliptic orbits, Appendix B for hyperbolic orbits, and Chapter 5 in universal variables, which includes the parabolic case not covered elsewhere. For solution of the equation, only the Newton–Raphson iteration algorithm is mentioned and no guidance is provided for a starting value in the universal formulation.

In Chapter 4 there is a detailed discussion of the computation of the classical orbital elements, along with some helpful numerical examples. Alternative elements sets due to Delaunay and Poincaré are briefly mentioned but not the more recent equinoctial elements.

The two-point boundary value problem known as Lambert's problem is developed for elliptic orbits and universal variables. However, the entire chapter is 10 pages long and the brief treatment does not include properties of the solutions, terminal velocity vectors, etc. Also, the solution algorithm outlined is an old one from Battin's 1964 book, rather than the more powerful one in his 1987 book. But if someone wants simply to obtain the solution to a specific problem, the procedure cited should be adequate.

Chapter 7 contains brief discussions of several applications, including patched-conic interplanetary trajectories (although that term is not used), gravity-assist maneuvers (called planetary flyby and gravity turn), and shuttle ascent and deorbit maneuvers. Relative motion in Earth orbit is discussed, but not the linear, Clohessy–Wiltshire equations used in much of the shuttle maneuver analysis.

Two hefty chapters on Perturbation Theory and Special Perturbation Methods are fairly thorough. A short chapter specifically on Runge–Kutta methods is provided, and the final chapter on Types of Perturbations considers third-body effects and nonspherical potential functions, although specific examples, such as an oblate planet, are considered along with atmospheric drag in the earlier chapter on Perturbation Theory.

This book is a useful addition to the professional library of anyone working in astrodynamics. Parts of it could also be suitable for courses in astrodynamics.

References

[1]Battin, R. H., *An Introduction to the Mathematics and Methods of Astrodynamics*, AIAA Education Series, AIAA, Washington, DC, 1987.

[2]Wiesel, W. E., *Spaceflight Dynamics*, McGraw–Hill, New York, 1989.
[3]Szebehely, V. G., *Adventures in Celestial Mechanics*, Univ. of Texas Press, Austin, TX, 1989.
[4]Chobotov, V. A. (ed.), *Orbital Mechanics*, AIAA Education Series, AIAA, Washington, DC, 1991.
[5]Prussing, J. E., and Conway, B. A., *Orbital Mechanics*, Oxford Univ. Press, Oxford, England, UK, 1993.

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