Tools of the astrophysicist

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The Physics of Astrophysics. Volume 1: Radiation. Volume 2: Gas Dynamics. By Frank H. Shu. *University Science Books/ W. H. Freeman: 1991. Pp. 429 (vol. 1)/476 (vol. 2). $46.50, £29.95 each.*

Downtown fishing. The Columbia River flood of 1894 was the largest recorded flood on the river in Oregon history. With a peak flow exceeding one million cubic feet per second, the flood provided angling opportunities in Portland for the boys of the Crystal Palace saloon. This picture is taken from *National Water Summary 1988–1989: Hydrologic Events and Floods and Droughts*, the sixth in a series of reports on the water resources of the United States. Published by the US Geological Survey, price $39.

MOST astrophysicists derive immense pleasure from the sense that they are engaged in unlocking a great puzzle, provided with clues often no more substantial than stray photons from a distant source, a knowledge of physics and an ability to describe the Universe through the language of mathematics. Frank Shu, whose interests span the scales from planets to galaxies and who is the author of a noted introductory text for undergraduates, has now written a uniquely detailed yet comprehensive graduate text in which he aims to teach the physics and mathematics that form the essential tools of the astrophysicist.

In volume 1 on radiation, Shu provides a broad introduction to radiative transfer and statistical mechanics and to both classical and quantum theory of radiation processes. In volume 2 on gas dynamics, he introduces kinetic theory and hydrodynamics, devoting about half the volume to laminar and turbulent flow, waves and shocks. The last third covers magnetohydrodynamics and plasma physics.

Those with a 'liberal arts' background may find themselves in need of some additional preparation to use this text, and parts might challenge those whose undergraduate education is limited to the physical sciences. Further, I suspect that there are rather few educators with sufficient depth and breadth of knowledge to feel comfortable teaching the complete one-year course for which the volumes are intended. But many teachers and researchers will want the two volumes on their shelf as a reference source and as a template for courses less ambitious than Shu's.

Despite the high level at which the volumes are pitched, they are clear and practically oriented. For example, in the coverage of the set of equations derived by taking moments of the radiation transfer equation, the justification for closure is presented in a plain, down-to-earth manner, and within the discussion that follows, the use of dimensional analysis for the solar interior gives the reader a true appreciation of the validity of the radiation conduction approximation. The topic of spiral density waves is used to introduce the concepts of wave packet and group velocity, and the 'method of characteristics'. This in turn leads to hydrodynamic flows, the classification of partial differential equations and a useful introduction to methods for their numerical solution.

Indeed, one of the most striking characteristics of the book is a linking of ideas and a remarkable absence of compartmentalization: classical radiation theory takes one naturally to plasma effects, and thereby to a chapter on basic plasma physics, while quantum radiation theory leads eventually to a discussion of the nature of chemical bonds. Further down this hierarchy one finds a myriad of edifying digressions: from plasma physics we meet the Cerenkov and Razin effects; from chemical bonds follows a discourse on the nature of the strong force.

There are fluctuations in the depth of treatment. For example, two chapters covering synchrotron radiation guide the student from the basic concepts to an effective working knowledge of the subject; but although the exposition of cosmic dynamo theory is very clear, I think that the student would still have serious difficulty in understanding a modern paper on the subject.

As befits a general astrophysics text, it is not encumbered with extensive references. Two references usually follow each chapter heading to guide the reader to original and more detailed discussions. Citations of textbooks are gathered together in a bibliography, but journal articles are not, making it slightly difficult to find half-remembered references. And given that the text will surely become a standard, it is a pity that it continues to perpetrate the usage of cgs units, just when the astronomical community is beginning to adopt SI units.

Both volumes contain nontrivial sets of problems that introduce additional material and exercise the student's mathematical and numerical abilities while probing the depth of his or her understanding. One sequence of problems works through the derivation of the electromagnetic fields associated with the Lienard–Wiechert potentials, and the vector potential and magnetic moment of a magnetized rotator. The sequence ends with a broad, open-ended exercise on the Crab pulsar, which will prove to be a considerable task for those who follow up the suggested literature search.

But that level of commitment is, I suspect, just what Shu expects. Students who opt to follow this pair of excellent texts are going to equip themselves with a strong background in the physics of astrophysics, and receive a compelling invitation to use this new-found knowledge to explore the many exciting areas of modern astronomy. □

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