

arms and thick star-formation ridges along the outer edges.

In the mid-1970s, the theory was extended by Lin and Bertin, along with Y. Y. Lau and James Mark, to include reflection and refraction of spiral waves at the inner disk boundary, amplification of the waves midway out in the disk, where the spiral pattern and stars corotate, and radiation of the transmitted waves to infinity beyond this. The result is the "modal" theory of spiral structure, which is the primary topic of this book.

The modal theory applies to spirals that are excited by internal disk processes only, independently of bars in the disk that may have formed by localized collapse or of tidal forces from nearby galaxies, both of which may also drive spirals. The two primary assumptions for the modal theory are that spiral waves refract or reflect off the inner bulge without suffering much absorption at a stellar resonance inside this point, and that the combined gas-plus-star disk is close to a state of marginal stability at the corotation radius. Both of these assumptions have been debated in the literature, but if they are true, then density irregularities in the disk, which excite weak spirals everywhere, can grow exponentially when the spirals they generate refract or reflect off the bulge and return exactly to their point of origin; there they amplify and turn back toward the bulge. Because these spirals travel with a certain speed, this amplification condition implies that only density irregularities within a small range of radii can excite growing wave modes of a certain order; these wave modes will then have corotation at that radius.

Spiral waves presumably grow until they get sufficiently strong that energy dissipation in gaseous shocks caused by the waves balances the input of energy from galactic rotation. At this point, the spiral pattern should be able to persist for several rotations with a constant shape and angular speed. Thus the modal theory solves the so-called winding dilemma faced by material arms (which wrap up quickly because of galactic differential rotation) and by free waves (which also wrap up as they propagate toward the center). According to the modal theory, most two-arm spirals are slowly evolving standing waves composed of both inward propagating tight spirals and outward propagating open spirals that draw energy from galactic rotation where they meet, at the corotation radius.

The book by Bertin and Lin begins with observations of galaxies as a motivation for suggesting that grand-design spiral structure requires an intrinsic mechanism of generation, inde-

pendent of bars and companion galaxies. It also discusses the small and irregular spiral features that are observed in galaxies in terms of pure gas phenomena. With this comprehensive point of view, the origin and maintenance of all types of spiral structure, the dynamical reasons for the various morphologies of galaxies, and the utility of spiral theory for modeling the distribution of total galaxy mass, including the dark halo, are all nicely covered.

The book is aimed at a nonspecialist audience interested in the modal theory of spiral structure. Other models for the origin of galactic spirals are not discussed, nor are the results of numerous computer simulations in the literature. There is also little about the stellar dynamical model of spiral structure; essentially all of the results and discussions of the modal theory emphasize the fluid approximation for stellar motions rather than stellar orbit theory, except for a few brief discussions of orbit resonances. Moreover, the book lacks the detail necessary for a student to determine the important quantitative properties of spirals, such as the gaseous streaming speeds, arm pattern speeds and arm amplitude variations. For these, the reader is advised to consult journal articles written by the authors.

The modal theory of galactic spirals is compelling and worthy of study by an astronomy community that continuously returns to the topic of spiral-arm generation, whether for galaxies, protoplanetary disks or other accretion disks. Spiral structure in galaxies is an extremely complex problem involving disk dynamics with unknown inner and outer boundary conditions and halo mass distributions, complicated partial couplings between stellar and gaseous subsystems, poorly understood processes of gas dynamics and star formation and, as in most fields of astronomy, inadequate observations of precious few good examples. Perhaps this book can deflect some youthful energy into this long-standing and important problem.

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Peer Instruction: A User's Manual

Eric Mazur

Prentice Hall, Upper Saddle

River, N.J., 1997. 272 pp.

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Eric Mazur writes in the introduction to *Peer Instruction*, "I have been teaching an introductory physics course for

engineering and science majors at Harvard University since 1984. Until 1990, I taught a conventional course consisting of lectures enlivened by classroom demonstrations. I was generally satisfied with my teaching—my students did well on what I considered difficult problems, and the evaluations I received from them were very positive. . . . In 1990, however, I came across a series of articles by Ibrahim Halloun and David Hestenes [about conceptual understanding in physics]. Intrigued, I decided to test my own students' understanding. . . . The results of the test came as a shock." Mazur's students, who could solve rather difficult problems, did poorly on what appeared to be very simple conceptual questions.

Dismayed at his students' poor performance, Mazur developed a teaching method, which he calls peer instruction, designed specifically to foster conceptual understanding. This book details his allocation of class time between short periods of lecturing followed by multiple-choice conceptual questions—"ConcepTests." After posing a ConcepTest question, Mazur has the students think about the question for one minute. Then comes the crucial part of the technique: Students talk to each other for two minutes, trying to convince each other of the correctness of their answers. The instructor then tallies the class responses, either by a show of hands or with electronic devices. Depending on the distribution of responses, the instructor makes a brief comment on the question (if almost all the responses are correct) or spends some time amplifying the crucial issues. The cycle of short discussion and ConcepTest question is repeated—perhaps four times during an hour's class. The results are impressive: Scores on conceptual tests have risen dramatically, and student enthusiasm for the course has increased markedly.

What do we have to give up to achieve this improved conceptual understanding? Not much, by Mazur's account. The students get the basic information and derivations from a standard textbook. In fact, for the peer-instruction method to work, the students must do their text reading before coming to class. Mazur describes a method of using short quizzes at the beginning of each class to ensure that the students have read the material. Traditional problem solving is covered in homework assignments and recitation sections.

The book contains a wealth of material to assist an instructor who wishes to use peer instruction. The so-called force concept inventory and mechanics baseline test—two widely

distributed tests of conceptual understanding of introductory mechanics—a set of reading quizzes and a full set of ConcepTest questions are included both in the text and on two diskettes that come with the book. Mazur discusses ways to organize a lecture around the ConcepTests and to set up the course to make use of peer instruction.

Why does peer instruction work? The crucial point is that students are forced to articulate and defend their conceptual understanding. Both the students and the instructor get immediate feedback about their successes and failures. By moving around from group to group, the instructor quickly gets a sense of where student misunderstanding lies. Each student soon realizes that other students in the class are having the same difficulties.

Mazur has shown how interactive engagement techniques, usually associated with small classes, can be applied in a large lecture setting—for better or worse, the situation in which most introductory physics students find themselves. Peer instruction is a pedagogical strategy that can be applied, in principle, to a wide variety of courses. However, in its present implementation, the ConcepTests focus on the traditional introductory physics topics. There is little emphasis on physics as a method of inquiry, and few of the ConcepTests deal with contemporary physics topics. Instructors who wish to use a nontraditional curriculum will need—at least for now—to write their own sets of conceptual questions. That, however, is an initial investment that seems well worth the effort.

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Fragile Objects: Soft Matter, Hard Science, and the Thrill of Discovery

Pierre-Gilles de Gennes
and Jacques Badoz
Translated by Axel Reisinger
Springer-Verlag, New York, 1996.
189 pp. \$24.00 hc
ISBN 0-387-94774-4

Pierre-Gilles de Gennes is one of the founders of soft condensed matter physics. He is the author of classic monographs on liquid crystals and polymer physics upon which a whole generation of condensed matter physicists was raised. He received the Nobel Prize in 1991 for his contributions to soft condensed matter physics. Fol-

lowing the award, he was invited to numerous schools and science clubs to talk about his research, his views on science and the work of a scientist. The book *Fragile Objects* is based on these lectures and discussions. It is written for a very broad audience: from advanced high school students and undergraduates to graduate students, from mature scientists to inquisitive readers interested in the problems and dilemmas of modern science. The book

does not assume any knowledge beyond high school physics. Many of its sections, related to educational and social issues, do not require any knowledge of physics.

Reading the book can be compared to strolling through a magnificent garden of fragile objects. De Gennes gently guides the readers past the beautiful landscape of soft matter and tells us how it was uncovered. We see many colorful examples of fragile objects that

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