The Fundamentals of

PHYSICS

Volume II

Using Models

Instructor Guide

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To the instructor

Approach

> The fatal pedagogical error ... to throw answers, like stones, at the heads of those who have not yet asked the questions. Paul Tillich (as quoted by Julian Weissglass on page 59 of *Exploring Elementary Mathematics*, 1979, W.H.Freeman & Co.)

Ideally, content is provided in response to questions. In this respect, all texts necessarily fail. Without one-on-one interaction, it is impossible to wait until students ask a question in order to provide the content. This text attempts to address this deficiency by providing puzzles at the beginning of each chapter and questions (representing common student concerns) at regular intervals within the text to initiate the introduction of new content.

The puzzles not only provide the rationale for the readings but are designed to promote questioning on the part of students. The instructor is expected to support this approach by first allowing students to explore concepts, phenomena or situations much like those in the problems and investigate *what* happens before providing the explanation of *why* it is happening.

The readings are designed to support such an approach (i.e., exploration and investigation before explanation) as the selection of the content within the readings has been guided by questions I anticipate students may have.

Of course, providing answers in response to questions is not sufficient. We must also ensure that the student understands the answer. Unfortunately, even the most lucid explanations will not be fully understood or appreciated by most students. For this reason, it is the instructor's responsibility to make sure that students are given the opportunity to evaluate their own understanding as the student is in the best position to evaluate whether he or she fully understands the material. Neither the text nor the instructor can adequately do this.

Unfortunately, many students are not able to evaluate their own understanding. The result is a blind acceptance of "teacher-generated answers" even in cases when the answers fail to match the student's own conceptual understanding of how the world works. Such information is simply forgotten soon after the course ends, if not before.

It is expected, therefore, that instructors will structure the course in such a way that students are encouraged to participate in continuous self-assessment. In support of this, the readings provide "example" problems within the readings (for which solutions are provided) and "checkpoints" (homework problems) at the end of each section.

Note that the checkpoints are provided at the end of each section rather than at the end of the chapter. Such placement is important as it gives students an opportunity to evaluate their understanding before moving on.

Also note that these problems are called "checkpoints" instead of "homework" or "practice" because it is crucial that both the text and the instructor stress the importance of active learning (sometimes called "active thinking") and self-assessment.

The checkpoint questions are designed so that students can answer them quickly without going through a lot of calculations. An answer key to the checkpoints is provided, and the instructor is strongly encouraged to make it available to students.

At the end of each chapter, there are additional problems. These are the typical physics problems usually assigned for homework and practice.

✍ It is common for students to short-cut the process by reading the checkpoint or problem first and then reading "backwards" to find the answer. Emphasize to the students that they shouldn't do this. Sometimes the checkpoint or problem only addresses a small part of the readings or may merely ask the student to recall a portion of the reading, so reading "backwards" may be sufficient for answering the question but will cause the student to miss the over-arching "big idea." In other words, just because a student can answer a checkpoint or problem correctly does not necessarily mean that the student understands the readings.

Students should be encouraged to reflect on the main ideas. As such, important ideas are highlighted in the margins. At the end of each chapter, there is a summary that reflects upon these important ideas. Ultimately, however, it is the student alone who is best able to evaluate his/her understanding.

It is important to note that this text only *supports* what the course should be asking the student to do. It assumes the instructor has structured the course in such a way that supports the cycle of exploration and evaluation described above. The instructor is expected to avoid being the "source of all information" as such a role de-emphasizes the need for students to evaluate their own learning.

This is not easy to do for most instructors. Indeed, one shouldn't be surprised if, as the instructor, you find it difficult to "guide" your students' learning. In my experience, there are two major hurdles that must be overcome. First, students must "buy into" the idea that the "instructor as guide" model is better than the "instructor as the source of answers" model. The instructor must actively "sell" the idea that it is best to have a classroom in which the instructor guides student self-reflection and evaluation of concepts. As part of this, you might want to provide evidence in support of this.

Second, the instructor must provide enough "scaffolding" so that students are prepared to evaluate their own learning. The textbook has been constructed to scaffold the necessary concepts but many students simply do not have the skills to evaluate their own learning. Even if they want to, some students cannot carry out their self-evaluation without some support. This can be very time consuming for the instructor and may be quite difficult given the background of the student and/or the number of students in the class. Still, it is imperative that the instructor recognize that many students do not automatically have the skill to evaluate their own learning and thus the instructor must be supportive and understanding of problems students will inevitably encounter.

The third problem comes from ourselves. More often than not, you may find yourself giving students "the facts," using the rationale that there is no easy (or time-efficient) way to have students explore or evaluate the concept or skills in question. In many cases, a little thought or collaboration will reveal that, on the contrary, it *is* possible. In almost all cases, a little research into what has been done by others will show that others have already found a way to address the problem in a time-efficient way. The instructor is encouraged to look into the published literature outlining the methodologies that support the learning cycle and student inquiry. It need not be an earth-shattering change in one's instructional technique but it does need to be a purposeful change.

Content

The purpose of the book is to have students master both the skills and concepts of physics. Both are crucial, not only in physics but also the other sciences. Consequently, rather than assuming the skills are already mastered, this text explicitly makes them part of the objectives.

The focus of the book is on how scientists use conceptual models to make make sense of phenomena. The organization of the book is as follows. The sequence of the topics was chosen consistent with the philosophy described above, where students must be exposed to the rationale for studying something before studying it.

The first third of the book examines the different ways we describe gravitational, electric, magnetic and nuclear interactions – via forces, fields and energy.

Part A looks at forces. The relationship between mass and the gravitational force is reviewed prior to exploring the relationship between charge and the electric force, where the atomic model is explored in order to make predictions about electric interactions. This is then expanded upon when the nucleus of the atom and the associated nuclear interactions is discussed (along with decay). With magnets, the magnetic force is described and compared to the electric and gravitational forces.

Part B introduces the idea of a fields and energy. Gravitational, electric and magnetic fields are discussed and, to avoid a focus on plug-and-chug equations, I have removed discussion on the specific equations that give the field magnitude for different configurations. Gravitational, electric and nuclear energy are discussed after fields. Whereas in volume I the focus is on predicting the kinetic energy of an object, here the focus is on the energy transfers associated with separating or combining objects. This is first applied to gravitational situations (e.g., a rocket ending up so far away that it is no longer interacting gravitationally with Earth). It is within this context that chemical situations are explored (e.g., the breaking of a chemical bonds is essentially the separation of two electrically attractive objects). Finally, nuclear reactions are explored in terms of the breaking of the nuclear bonds.

The middle third of the book examines the flow of charge.

Part C examines why charge flows as it does and discusses current (which will be used with circuits in part D), electromagnets, and the flow of liquids through pipes (as a prelude to examining the flow of electric charge through circuits, with pressure being analogous to electric potential).

Part D examines electric circuits (both DC and AC). Although many students do not need to know the details of AC circuits (and, indeed, AC circuits are frequently ignored in courses catering to life science majors), I believe that it is necessary for students to not only describe an AC signal (as it helps them understand household wiring and provides the language that will be used for waves in part E) but also understand how the presence of an AC voltage can impact an object differently than DC (resistors, capacitors and inductors serve to illustrate characteristics that organisms can have). A chapter on induction is included simply because it follows from what has come before and allows students to explain several types of phenomena (i.e., motors, magnetic braking and transformers). It can be deleted as it is not directly related to the typical audience of this course.

The last third of the book examines wave-like phenomena.

Part E introduces the language and properties of waves by focusing on sound for the most part, with an examination of the Doppler effect and interference effects (including standing waves).

Part F examines optical phenomena, including diffraction, reflection and refraction, and the impact of mirrors and lenses. The creation of images and what that means is also discussed in this part.