REVIEW: Chapters 22-27

Sears, Zemansky & Young, 8th Ed.

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Introduction

Let me begin by describing my own attitudes concerning entry level University Physics courses, which are certain to color my critical reactions to any textbook. While I feel that the traditional approaches of both Sears, Zemansky & Young (SZY) and Halliday and Resnik (HR) are preferable to the various "Physics-is-Fun" texts of the 1960's and 70's, I think there are certain basic flaws in the traditional organization of material that tend to fragment the introductory course from the intermediate and advanced physics courses that follow it. The course one must teach from SZY and HR seems to me to be very much grounded in the thought of the 1850's, and physics of the 1900's is grafted on rather than used as a foundation.

In the entry level course students are taught that: mechanics is totally separate from electricity and magnetism; contact forces occur because matter is solid and hard and has no electromagnetic origin; electricity involves pith balls and amber rods which occur only in physics lectures or in dangerous appliances that you plug into the wall (despite the wonderful fact that all matter consists of little bits of positive and negative electricity in perpetual motion) ; the universe is governed Laplacian determinism, all systems are linear, and quantum mechanics concerns only the microscopic (despite modern views of chaos as the norm, and nondeterministic quantum gravitation as the beginning and end). It is possible to define a system in which all particles or charges are at rest, and "at rest" is an absolute thing, independent of the observer. Even when these static forces produce accelerations, the charges remain static. Magnetism is quite separate from electrostatics, and the latter can be studied as if the former did not exist. I realize that the weaving in of the modern atomic picture, the inclusion of relativity as the essential basis of electricity and magnetism, the limitations of linearity, etc., may seem like a tall order for an elementary text, but my experience is that the students can handle the drudgery (which I think is still necessary) of a problems-related course better if you give them a modern "big picture." Furthermore, the press of time in a crowded curriculum requires a reduction of the material studied, particularly in the case of naive pictures that will need to be corrected in a higher level course.

The tendency of new editions of older textbooks is to include new topics (*e.g.*, room temperature superconductivity, quark theories, *etc.*), but older topics are seldom removed. I see two possibilities for reducing material to a manageable level while adding new topics: (1) Replacing heuristically inductive developmental sections with an introductory presentation of modern view. Historical evidence (and misconceptions) can then be understood through a quick review, explained in the context of the modern view. (2) Removal of some of the cherished applications that have largely disappeared from the experience of today's students (born around 1970).

All of this is a quite personal view, and I may not represent a significant market targeting group. However, some of my desires in a textbook might be met with small shifts in emphasis, without alienating other marketing targets, so I have included my candid comments as I have read the draft.

The comments I have penciled into the manuscript represent my spontaneous reactions to my reading of the manuscript, or the reactions I might expect from students or colleagues. I have made these comments as I read the manuscript, and sometimes my earlier criticisms were answered in subsequent text. I apologize to Dr. Young if my comments are sometimes overly enthusiastic for my own taste and way of saying things, and may not take into account the realities of the highly competitive marketplace. However, I have assumed that my role is more to criticize than to praise. I have been especially picky concerning statements of fact that are (perhaps subtly) flawed by modern views. My comments tend to be negative, because there is little to be said about the sections I especially like. I hope that some of my suggestions are useful.

Content

Concerning the content, I think that most of the important material is being covered, although sometimes there may be too much detail. We have a one year five hour course to cover this material, and invariable we run out of time and slight chapters late in the textbook. It is difficult to make cuts in individual chapters, because the students are then confused about what material they are responsible for. As new topics are added, textbooks seldom remove material to make room for them. One could to exclude whole chapters, but this leaves large gaps. I would like to see several sections shortened.

Chapter 23 on Gauss's law spends a lot of time on vector calculus, deriving the divergence theorem, defining the dot product (wasn't that already done in the section on energy?), discussing surface normals, *etc.* I don't think it is necessary to derive the divergence theorem in section 23.1. All students who are on a technical line will see the divergence theorem and Stoke's theorem in several concurrent and subsequent courses. For students who are terminating their physical science studies with this course, a short qualitative presentation would suffice.

I would also reduce or eliminate sections 25-3 and 27-1 (Capacitors in series and parallel, and Resistors is series and parallel). Since elementary textbooks always contain more topics than can be covered in the time available, it does not seem prudent to pad textbooks with subjects simply because they provide material that is easy to test. In some cases this is actually disinformation. In discussions with former students, I find that there are four things that they can all recall from their sophomore physics course: (1) Series resistors add directly; (2) Parallel resistors add as reciprocals; (3) Series capacitors add as reciprocals; (4) Parallel capacitors add directly. Textbooks place great emphasis on these facts and often claim that this knowledge will be useful. My electronics technician says he can't recall using these four "laws" in a practical application. If someone can provide me with the name of one person who has soldered together the wrong resistors and capacitors to make something useful, my apologies will be forthcoming. The better students look at the definitions $V = Q/C$, $V = (dQ/dt)R$, and $V = (d^2Q/dt^2)L$, and correctly conclude that someone who died in 1867 defined capacitance upside down relative to resistance and inductance, which is not a major concern today. What is worse, these non-laws break down when emfs are embedded in the loops. I may be out of sync, but I would welcome a text that axes out this sort of thing.

Equations for the "coefficient of linear whatever" in the form $X = X_o[1 + \alpha(T - T_o)]$; $(T \cong T_o)$ occur again and again in elementary textbooks. Since any quantity X that is a single-valued function of any quantity T can be represented by this expression (for T not too different from T_o), to quote Pauli, "it isn't even wrong." It is a truism. (However α is, of course, a function of T_o.) Many students now have a polynomial regression program built into their pocket calculators, and realize that they wouldn't stop with a linear approximation in a real application anyway. The section on the free electron theory of conduction clearly defines the nonlinear nature of resistivity in terms of the temperature dependences of conduction bands, lattice scattering sites, inter-collision times, *etc.* Why try to linearize something that has been so persuasively demonstrated to be nonlinear?

In the table of contents that I have, the book seems to end with Chapter 39, Relativistic Mechanics. Earlier editions of the book had additional chapters entitled "Photons, Electrons and Atoms," "Quantum Mechanics," "Atoms Molecules and Solids," and "Nuclear Physics." I hope these chapters are still intended to be included.

Organization

In the organization I would make a number of changes. I would place section 22-3 (Conservation and Quantization of Charge) before 22-1 and 22-2. I think students can understand the historical phenomenology better if they understand the fundamental origins first. I would prefer to see section 24-5 (Potential Gradient) ahead of section 24.1. I find that students are much more comfortable with differential calculus definitions than with integral calculus formulations. The integrations of section 24.1 are much easier when the integrand is an exact differential.

The extensive treatment of series and parallel resistors and capacitors, circuit equations, *etc.*, provide good mathematical exercises, and problems that are easy to grade on homework and tests, but are they really more important than some of the topics that would come after chapter 39? Do linear circuit elements have the same importance today that they had before large scale integrated circuits? It used to be that these topics provided a physics introduction to higher level engineering courses. Now it has turned around, and engineering students learn these old methodologies only in their physics courses, and learn their modern physics only in their electrical engineering courses. Will any of our students ever see an old fashioned carbon resistor, much less need to read the color code? (I think this is manifestly the wrong year to add a section teaching the students to read the resistor color code! If it were there before this would be the year to remove it.) Wouldn't a highly magnified picture of the architecture of a large scale integrated circuit be more familiar to today's students? Even if you can find a circuit board with carbon resistors on it, the TV repair man will swap out the board, and not replace a resistor.

The chapter on Relativistic Mechanics is placed near the end of the book, and deals exclusively with the standard popularized apparent paradoxes of length contraction and time dilation (sometimes called "Gee Whiz" Physics). Some textbooks have now had the courage place this chapter in the electricity and magnetism section, where it rightfully belongs. The

Biot-Savart law can be readily deduced from the electric fields due to a negative line charge drifting through a positive line charge, viewed by a moving observer. This requires only Coulomb's law for a line charge $F = 2kQq/rL$ and $L = L_o(1 - v^2/c^2)$, with binomial expansion to order (v/c) of the latter. This simple development opens new horizons to the students, and corrects some of the naive concepts from ancient Greece that for some reason still haunt our elementary physics courses.

Level

I would pitch the level of some of the sections a little higher. Our students supposedly have a background in calculus that we should draw on. Time is limited, and we cannot slight physics sections at the end of the book for the benefit of students who have not learned the prerequisite math. For example, as mentioned above, I don't think it is necessary to derive the divergence theorem in section 23.1.

Accuracy

I wish that textbooks (this one included) would do a better job of differentiating between laws of physics (*e.g.* conservation of energy and momentum, Newton's law, Coulomb's law, *etc.*) and phenomenological linearizing approximations (*e.g.* Hooke's law, Ohm's law, Young's modulus, the definitions of dielectric capacitance and diamagnetic inductance, coefficients of linear whatever, *etc.*). These linearizing phenomenologies exist only in textbooks - the real world is highly nonlinear, and their presentation inaccurately represents modern scientific thought. The weaker students consider all "formulas" in the book to be equally valid, and should all be memorized. The stronger students are aware of nonlinear chaos, fractal escapes, and regard their general physics course as an anachronistic relic. I think that definitions of various nonlinear bulk moduli such as $V = IR$, $V = Q/C$, $V = L(dI/dt)$, $F = -kx$, *etc.*, should be clearly labeled, so they can not be confused with the laws of physics.

There are also discussions which use words such as "always" to describe situations that are only valid for electrostatics, and in some cases the validity is even qualified there. It should be possible to construct statements that are not only simple, but properly qualified so as to be correct.

The numerical precision is generally adequate. However, I would avoid the practice of adding zeros as insignificant digits to fixed point numbers. For example, in section 27-7, the mass of the electron is 511 keV or 5.11x10 eV, but not 511000 eV (510999).

Examples

I am reasonable well pleased with the examples. I particularly like the recurring use of the dipole as an example, but I wish that the fact that the dipole-dipole force is the origin of virtually all the forces we feel in daily life could be emphasized. It is worth pointing out to the students that they sit statically in their chairs because the force of gravity pulls them down and the dipole-dipole polarization of their posteriors and the chair seat pushes them up.

Writing Style

I have some reservations about the "relaxed, less formal" style. To the extent that this means the use of concise, simple declarative sentences, it is desirable. However, I see an attempt to incorporate slang into the text, presumably to make the subject seem more friendly. I think this is risky. Slang is very culturally specific, and an author should be very careful about injecting a cultural bias into a general educational instrument. I think most middle Americans would be alienated by a physics text written in Black English, and conversely we must be sensitive to black, hispanic, foreign, *etc*, students who do not share our slang idiom. Fortunately, the use of slang is only occasional in the chapters before me, but if used at all, it should be done very carefully, with sensitivity to groups who do not conform to the "Ozzie and Harriet family," but who comprise valid marketing targets.

In seeking a relaxed style, there seems to be a global replacement of certain subject-predicates with contractions, which also concerns me. The use of "there's" for "there is," etc, may be all right occasionally, but I know that students to whom English is not the first language (who comprise more than 50% of the students in our elementary physics course) claim that the negated contraction is one of the English language's weakest features. The fact that "I am not" is contracted as "I'm not" and "you are not" is often "you aren't" robs us of a standard negation identification with "not." Be careful that the breezy use of contractions that has been adopted throughout this text does not have an unintended backlash.

Certainly any use of bad grammar to make the book seem more "friendly" will irritate the bright and literate students, and defeat the purpose of the programs for deficient students such as the "Writing Across the Curriculum" movement that is sweeping American Universities. These programs seek to integrate the learning of language skills into all courses, and it is precisely the wrong time for a Physics text to receive low marks from English departments (such interdisciplinary reviewing could occur as part of these programs). In my language it is "I/we shall, you will, he/she/it/they will," for normal usage, and "I/we will, you shall, he/she/it/they shall" to show determination. In the present text "we" seem resolutely determined in even the simplest of problems.

In general, the prose is very polished, and reflects the fact that the text has been tested and reworked over many years. There are many sections that I like very much, and would not want to see a single word changed. I particularly liked the sections: 22-3 Conservation and Quantization of Charge; 24-6 The Millikan oil-drop, 25-6 Molecular Model of Induced Charge; the Superconductivity discussion at the end of 26-2; 26-6 Theory of Metallic Conduction; 26-7 Physiological Effects of Currents; and 27-5 Power Distribution Systems.

Applications

The applications seem adequate, and I would not strive too hard at applications. Some of the failed texts of past decades allowed their applications to drive their presentation of material (ie, by teaching only the concepts that were required for specific engineering, biomedical, etc, applications). Trying to conceal pulleys and levers inside arms and legs, or linear circuits inside nonlinear biological systems, only confuses the students. Unfortunately, the simple standard applications are often the best.

Competitive Position

Our physics sequence consists of three 10 week quarters with 5 credit hours (two lectures, three problems sessions, plus a laboratory). It would therefore be necessary for us to cut up the chapters in a non sequential manner. I would like to cover the material in chapters 1-14 in the first quarter, but that would be impossible, so something would have to be left out. The second quarter would consist of Chapters 22-33, leaving Chapters 15-21 and 34-38 for the third quarter. This would require moving ahead at about 1.25 chapters per week, and when I finish, the year is still 1850. I would prefer to see a number of things in another order. I would like to see chapter 12 (Gravitation) placed between chapters 5 an 6. I would like chapter 39 (relativistic mechanics) placed between chapters 28 and 29, and rewritten to emphasize its relationship to the magnetic field (Einstein's relativity paper was titled "On the electrodynamics of moving bodies," not "what happens on pathological rocket ships"). Even if chapter 39 could be included, the book ends in 1905, unless the table of contents I have is incomplete.

In the past few years, HR has received heavy usage in our calculus-based courses. I have not been directly involved in this choice for a few years, but a new adoption is being considered, and HR, SZY, and Serway are certainly in the running. A major change is always difficult, since faculty members acquire lists of problem assignments of known complexity, sets of lecture notes, and modes of presentation, all of which require extra time (in short supply) to revise to suit a new text. The reasons for a change must therefore be quite compelling, but the transition can be eased by the existence of solutions manuals, computer test banks, overhead transparencies, computer software, etc. There is a general feeling that this course should be revised, but a lack of agreement on the direction. However, I believe that all are in agreement that this course contains far too much material, and students are not succeeding in "getting a drink from a fire hose."

While it is not directly relevant to this textbook, I have recently been responsible for the choice of the our noncalculus text, and, since I chose to replace the use of Sears, Zemansky, and Young "College Physics" by another text, it might be useful for me to explain my reasons. Since the noncalculus course is a scientific dead end (*ie*, a prerequisite for nothing), we feel that this survey course absolutely must include some of the physics of this century. Thus, the catalog description of this course is quite different from that of the calculus-based course. The first quarter deals with mechanics, fluids, and elasticity. The second quarter treats heat and electromagnetism. The third quarter deals with the many manifestations of light: geometric and physical optics, relativity, quantum theory, spectroscopy, etc, as well condensed matter and nuclear physics. It is very hard to compress the chapters of SZY-College into two quarters (it requires a lot of skipping) and another text would be needed to fill out the third quarter. There is certainly some sentiment within the department to make similar (but less drastic) revisions in the calculus-based sequence.