Instructor's Resource Manual

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PHYSICS

for Scientists and Engineers

THIRD EDITION

FISHBANE | GASIOROWICZ | THORNTON

Instructor's Resource Manual

to accompany *Physics for Scientists and Engineers 3rd edition*, by Paul M. Fishbane, Stephen G. Gasiorowicz, and Stephen T. Thornton

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Introduction to the Instructor's Resource Manual

In writing the *Instructor's Resource Manual for Physics for Scientists and Engineers*, third edition, by Paul Fishbane, Stephen Gasiorowicz, and Stephen Thornton, I have those instructors in mind who are new to teaching physics or this particular course. I hope that experienced instructors will find this manual useful as well. I have had the opportunity to teach the so-called *physics for poets* course to liberal arts students, the algebra-based course for non-engineering science majors, and the calculus-based course for the engineering majors. I have taught physics at a Community College as well as at a major Research University. This manual draws heavily from my many years of experience in these different situations. Obviously, teaching styles vary, and so I hope you will use the material in this manual to suit your particular style.

The majority of students in this course will be aspiring engineers who will come in with the view that physics is a hard subject to master. Many would not have had any physics in high school. In two semesters, we try to cram in as much material as we can and expect the students to achieve a certain level of mastery. It is no wonder that they have this built-in fear of the subject. It is hence very important that we as instructors, address this fear from the very beginning. Physics is a very logical subject. It is certainly not just a course with a bunch of formulae that students can plug numbers into. A lot will depend on our approach to teaching, how well prepared we are, and how interesting we can make the class. So the more structured the class is, the more successful we will be in easing students' anxieties and fears.

Demonstrations and visual aids will stimulate students' interest in the subject matter. Try to relate the concepts to a particular field of engineering, wherever possible. This always helps students to realize why they are enrolled in this class. Show them why they need a good foundation in physics if they want to be nuclear engineers, chemical engineers, aeronautical engineers, civil engineers, computer science engineers, etc. Discussing the connection between the topics in the textbook and the cutting edge research in these areas will help maintain students' interest in the subject matter. It is very important that we do not reduce the class to a mere discussion of what students perceive as physics that has nothing to do with the present-day world.

Course Organization and Structure

As mentioned earlier, how successful your semester is will depend on how you structure the course and how organized you are. Providing students with a syllabus that includes reading assignments, homework assignments, test dates, and grading scheme will ensure that students learn to structure their studies around this syllabus.

Quite often we tend to forget how difficult it is to keep one's interest on task for the full 50 minutes. To keep the students' attention from wandering, minimize the time spent on lecturing and try to vary the format of the class. Discussion of the previous day's material, a quick quiz at the beginning or end of class, five minutes to address concerns regarding homework assignments, a demonstration to introduce the next topic, cooperative learning through group problem solving could all be used at various times during the class to maintain a level of interest that is conducive to learning. Encourage students to be active learners by encouraging participation in class.

How often we have heard the litany that problem solving is very hard. To demystify this task, be sure to solve problems in a structured and systematic way in class every time you work an example on the board. If possible, schedule an hour of problem-solving sessions each week when you can make yourself available to help students. Better yet, have it in a classroom where you can encourage students to work in groups and you can circulate around as a facilitator. Homework assignments ensure that students learn to work problems on their own, and it also provides you with some valuable feedback. Finding time to grade problems is not always easy. However, for students to value the homework assignments and to ensure that they are an effective learning tool, consider grading at least part of the assignment each week. There are several on-line homework delivery systems available that take away the grading chore from your busy schedule. Consider using one of these if possible.

Quizzes and tests are important for two reasons. First, they encourage students to not get behind in the course. Second, they provide the necessary feedback to you and the students. You, as the instructor, will be able to evaluate your students on a regular basis. The students, for their part, will know how they are performing in class and accordingly modify their approach to the course.

Quizzes need not take up too much of class time. A quick quiz at the beginning or end of the class followed by a discussion of the correct answers will help students clarify questions they may have on the material covered in the previous class. It will encourage them to attend class regularly and keep up with the reading assignments before each class. As an option or in addition to in-class quizzes, consider giving a web quiz before each class. Use the Just in Time teaching method (see reference on page xxi, preface to the textbook) to get feedback on students understanding (or lack thereof) of the material discussed in the previous class.

Three to four tests per semester and a final exam is standard practice for most physics courses. While we may feel that tests take up valuable class time, it helps to keep students on track during the semester. If you are responsible for the tests, consider including a good mixture of conceptual questions and problems. To de-emphasize memorization of formulas, consider providing a formula sheet. Some instructors allow students to bring an index card instead. However, it is hard to monitor the content of these cards. In some large departments where there are multiple sections of the same course, the tests are written by one faculty member (or a committee) and administered at a common time to all the students. If such is the case, it might be good to have an idea of the kind of test given in your department to ensure that you have covered the required material and done so on time for the test. There will always be students who will miss a test and need to make it up at a later date. Makeup test policy should be clearly outlined in the syllabus and consistently applied through the semester.

How the course is graded will depend on the different components to the course as well as departmental practices. Whatever the grading scheme, it is very important that it is clearly stated in the syllabus and explained to students at the beginning of the semester. If changes are to be made midway through the semester, these should be consistently applied to all students in the class. See the suggested grading scale included in the sample syllabus.

Sample schedules

Most departments offer either three 50-minute meetings or two 75-minute meetings per week for 15 weeks. The sample schedules given below address both of these options. Time is allowed for three tests per semester or two tests per quarter. The final exam is a comprehensive one, and it is assumed that there is a separate time period allotted for the exam at the end of the semester or quarter. Note that the second semester covers more material than the first one. Hence, you will find the schedule to be very tight. If you decide to omit certain topics, try not to exclude relativity and quantum physics.

SCHEDULE FOR A TWO-SEMESTER COURSE: FIRST SEMESTER Mechanics, Oscillations and Wave Motion, Fluids, and Thermodynamics		
Chapter	No. of 50-min. lectures (3/week)	No. of 75-min. lectures (2/week)
Ch. 1	1	1
Ch. 2	2	1.5
Ch.3	2	1
Ch. 4	2	1
Ch. 5	2	1.5
Test 1	1	1
Ch. 6	2	1
Ch. 7	2	1.5
Ch. 8	2.5	1.5
Ch. 9	2	1.5
Ch. 10	2.5	1.5
Test 2	1	1
Ch. 11	2	1.5
Ch. 12	1.5	1
Ch. 13	2	1
Ch. 14	2	1.5
Ch. 15	1.5	1
Test 3	1	1
Ch. 16	2.5	2
Ch. 17	2	1
Ch. 18	2	1.5
Ch. 19	2.5	2
Ch. 20	2.5	1.5
Review	1.5	1
TOTAL	**45**	**30**

SCHEDULE FOR A TWO-SEMESTER COURSE: SECOND SEMESTER Electricity and Magnetism, Optics, Modern Physics, and Quantum Mechanics		
Chapter	No. of 50-min. lectures (3/week)	No. of 75-min. lectures (2/week)
Ch. 21	2	1
Ch. 22	1.5	1
Ch. 23	1	1
Ch. 24	1.5	1
Ch. 25	1.5	1
Ch. 26	1.5	1
Ch. 27	2	1
Test 1	1	1
Ch. 28	2	1.5
Ch. 29	2	1
Ch. 30	2	1
Ch. 31	1.5	1
Ch. 32	2	1.5
Ch. 33	1.5	1
Test 2	1	1
Ch. 34	1.5	1
Ch. 35	1.5	1
Ch. 36	1.5	1
Ch. 37	1.5	1
Ch. 38	2	1
Ch. 39	2	1
Test 3	1	1
Ch. 40	1.5	1
Ch. 41	1.5	1
Ch. 42	1.5	1
Ch. 43	2	1.5
Ch. 44	2	1.5
Ch. 45	1.5	1
TOTAL	**45**	**30**

The schedule for the quarter system, as you can see, is not as balanced over the three quarters. This is unavoidable if you do not wish to split major topics between quarters. A second option (which is not my preference) would be to switch wave mechanics and thermodynamics and move fluids to the third quarter.

SCHEDULE FOR A THREE-QUARTER COURSE: FIRST QUARTER Mechanics, Oscillations and Wave Motion, and Fluids		
Chapter	No. of 50-min. lectures (3/week)	No. of 75-min. lectures (2/week)
Ch. 1	1	1
Ch. 2	2	1
Ch. 3	1.5	1
Ch. 4	1.5	1
Ch. 5	2	1
Ch. 6	1.5	1
Ch. 7	1.5	1
Test 1	1	1
Ch. 8	2	1
Ch. 9	2	1.5
Ch. 10	2	1.5
Ch. 11	2	1
Test 2	1	1
Ch. 12	1.5	1
Ch. 13	2	1.5
Ch. 14	2	1
Ch. 15	1.5	1
Ch. 16	2	1.5
TOTAL	**30**	**20**

SCHEDULE FOR A THREE-QUARTER COURSE: SECOND QUARTER Thermodynamics, Electricity and Magnetism		
Chapter	No. of 50-min. lectures (3/week)	No. of 75-min. lectures (2/week)
Ch. 17	1	1
Ch. 18	1.5	1.5
Ch. 19	2	1
Ch. 20	2	1.5
Ch. 21	1.5	1
Ch. 22	1.5	1
Ch. 23	1.5	1
Test 1	1	1
Ch. 24	1.5	1
Ch. 25	2	1
Ch. 26	1.5	1
Ch. 27	2	1
Ch. 28	1.5	1
Ch. 29	1.5	1
Test 2	1	1
Ch. 30	2	1
Ch. 31	1.5	1
Ch. 32	1.5	1
Ch. 33	2	1
TOTAL	**30**	**20**

SCHEDULE FOR A THREE-QUARTER COURSE: THIRD QUARTER Optics, Modern Physics, and Quantum Mechanics		
Chapter	No. of 50-min. lectures (3/week)	No. of 75-min. lectures (2/week)
Ch. 34	2.5	1.5
Ch. 35	2	1
Ch. 36	2	1.5
Ch. 37	2.5	1.5
Ch. 38	2	1.5
Test 1	1	1
Ch. 39	2.5	1.5
Ch. 40	2.5	1.5
Ch. 41	2	1.5
Ch. 42	2.5	1.5
Ch. 43	2.5	2
Test 2	1	1
Ch. 44	2.5	1.5
Ch. 45	2.5	1.5
TOTAL	**30**	**20**

On the next page I have included a sample syllabus for Fall 2004. Note that it includes all of the pertinent information regarding class policies, attendance, reading and homework assignments, grading, test dates and makeup test policies.

Instructor:

Office: *Phone:* *E-mail:*

Office hours: 11:30–1:00 MW, 2:00–4:00 TH or by appointment

Text:

- The *prerequisite* for PY 205 is MA 141 with a grade of *C* or better.
- **Attendance**: University policy requires that attendance be taken in each class. More importantly, keep in mind that attending classes regularly and participating in class discussions is essential to your success in this class.
- **Homework:** The *homework grade* will be determined from the online homework assignments at WebAssign (http://webassign.ncsu.edu/student.html). The first required assignment, *Introduction to Webassign*, is an orientation to the system. Assignments are of two kinds: questions and problems. Questions will be based on material to be covered and will be due one hour before class. No extensions will be given on these. Problems are due one class date after the completion of the material. Extensions to problem assignments will not be given without valid reasons. **Check due dates for each assignment**.
- **Extra Credit**: Weekly extra credit assignments will be posted on Webassign as well. While these are optional, keep in mind that these will be used to determine your final grade at the end of the semester.
- **Quizzes**: You can expect an average of two quizzes per week and these will be on material covered in the previous class. There will be no makeup quizzes. The lowest quiz grade will be dropped.
- **Tests**: Test dates are indicated on the schedule. Makeup tests will not be given without prior permission. *Practice tests* from previous (regular) semesters are available online on the course homepage.
- The *final average* in the course is computed as follows:

Three tests	40%	(10% lowest, 15% each other two)
Quizzes	10%	(includes in-class work as well)
Laboratory	10%	
Homework	15%	
Final Exam	25%	
	100%	

- **Labs**: Even-numbered lab sections begin on August 23, and odd-numbered lab sections begin on August 24. Take your lab manual and a calculator to the first lab. ***You must receive a score of 50% or better in lab in order to pass the course.*** For additional lab information go to http://www.physics.ncsu.edu/courses/pylabs/.
- The *Physics Tutorial Center* (132 Withers) offers a variety of tutoring services on a walk-in basis. The PTC will be open Monday through Friday. The hours are posted online at http://www.physics.ncsu.edu:8380/ptc/.
- If you have any special needs regarding this course, please see me as soon as possible.
- University policies regarding academic integrity and accommodations of students with disabilities may be found at http://www.fis.ncsu.edu/ncsulegal/41.03-codeof.htm and http://ncsu.edu/provost/offices/affirm_action/dss/.

Weekly Schedule

Week	Date	Chapter & Section	Suggested Problems
1	Aug.16	Chap. 1: 1–6 Chap. 2: 1–6	**1**: **2:**
2	Aug. 23	Chap. 3: 1–6 Chap. 4: 1–3	**3**: **4:**
3	Aug. 30	Chap. 4: 4–6 Chap. 5: 1–5	**4**: **5:**
4	**Sept. 8 (wed)**	**Test 1**	
	Sept. 10	Chap. 6: 1–2	**6**:
5	Sept. 13	Chap. 6: 3–6 Chap. 7: 1–4	**6**: **7**:
6	Sept. 20	Chap. 8: 8–6 Chap. 9: 1	**8:** **9:**
7	Sept. 27	Chap. 9: 2–6 Chap. 10: 1–4	**9**: **10**:
8	Oct. 4	Chap. 10: 5–7	**10**:
	Oct. 6	**Test 2**	
9	Oct. 11	Chap. 11: 1–4 Chap. 12: 1–4	**11**: **12**:
10	Oct. 18	Chap. 12: 4–5 Chap. 13: 1–8 Chap. 14: 1–2	**12**: **13**: **14:**
11	Oct. 25	Chap. 14: 3–8 Chap. 15: 1–5	**14:** **15:**
12	**Nov. 1**	**Test 3**	
	Nov. 3 (Wed)	Chap. 16: 1–6	**16:**
13	Nov. 8	Chap. 16: 7–8 Chap. 17: 1–4 Chap. 18: 1–3	**16:** **17:** **18:**
14	Nov. 15	Chap. 18: 4–8 Chap. 19: 1–2	**18:** **19:**
15	Nov. 22	Chap. 19: 3–6 Chap. 20: 1–4	**19:** **20:**
16	Nov. 29	Chap. 20: 5–7 Review	**20:**
	Dec. 6	**FINAL EXAM**	

Special Dates:
Monday, September 6: Holiday/no classes
Thursday–Friday, October 7–8: Fall break
Thursday–Friday, November 25–26: Thanksgiving holiday

Teaching Resources

Supplementary Materials

As an instructor, it is important that you familiarize yourself with all of the available supplementary materials and use them at every opportunity. Besides this *Instructor's Resource Manual*, the authors and publishers of *Physics for Scientists and Engineers*, 3rd edition, have provided several additional resources as supplementary material. The *Instructor's Solutions Manual* (**Vol. I: 0-13-039157-3** and **Vol. II: 0-13-144741-6**) by *Jerry Shi* of Pasadena College, has detailed worked solutions to all end-of-chapter problems and answers to even-numbered "Understanding the Concepts" questions. Close to 3000 multiple-choice, short answer, and true/false questions can be found in the *Test Item File* (**0-13-039158-1**). These questions are referenced to the appropriate text sections and ranked by difficulty level for the users' convenience. Over 400 full-color transparencies of images from the text are compiled in a *Transparency Pack* (**0-13-039166-2**). Organized by chapter, the *Instructor's Resource CD-ROM Package* (**0-13-039150-6**) is a comprehensive package that has electronic versions of the above-mentioned resources. In addition, the CD-ROM package includes *TestGen.* which, in the authors' words, is "a powerful dual-platform, fully networkable software program for creating tests."

Prentice Hall has its own online homework system. To register and use this resource see *The PH GradeAssist Instructor's Quick Start Guide* (**0-13-141740-1**).

Besides these supplements that are directly connected to the textbook, there are additional resources that are invaluable to every instructor, new or experienced. See pages xxi–xxiii of the preface to the textbook for a complete listing and brief description of these resources.

Don't forget to visit the companion website to the textbook (http://physics.prenhall.com/fishbane). This website is intended for both the instructor and the students. Familiarize yourself with the resources to be found on this site and urge your students to use them as well.

Demonstration Resources

Demonstrations should form an integral part of any course. A good demonstration can get the concept across to students far more easily than words can. Try to involve the students as often as possible and get them to predict the outcome as well as explain what they observe. The demonstrations that I have suggested in each chapter of this manual are based on my experience as a faculty member of the department of Physics at North Carolina State University. I am fortunate in that we have a very active demo section that is well maintained and is continually updated. Don't hesitate to ask your colleagues for their favorite demos, try some new ones on your own, and refer to the well-tested resources listed below.

Edge, R.D., *String and Sticky Tape Experiments*. College Park, MD: American Association of Physics Teachers, 1981.

Ehrlich, R., *Turning the World Inside Out and 174 Other Simple Physics Demonstrations*. Princeton, NJ: Princeton University Press, 1990.

Ehrlich, R., *Why Toast Lands Jelly-Side Down:Zen and the Art of Physics Demonstrations.* Princeton, NJ: Princeton University Press, 1997.

Frier, G.D., and F.J. Anderson, *A Demonstration Handbook for Physic.* College Park, MD: American Association of Physics Teachers, 1981.

Mamola, K.C., editor, *Apparatus for Teaching Physics,* College Park, MD: American Association of Physics Teachers.

Meiners, H., editor, *Physics Demonstration Experiments*. New York: The Ronald Press Company, 1970.

Physics Education Resources

At first glance, this long list can be intimidating. Even if you are not overly interested in this area of research, use these resources to get an idea of what does and what does not work when teaching introductory physics.

Arons, A.B., “Cultivating the Capacity for Formal Reasoning,” *Am.J.Phys*. (September 1976), p. 834 – 838.

Arons, A.B., *A Guide to Introductory Physics Teaching,* (John Wiley & Sons, Inc., New York, NY, 1990).

Arons, A.B., *Homework and Test Questions for Introductory Physics Teaching*, (John Wiley & Sons Inc., New York, NY, 1994).

Beatty, I.D., and Gerace, W.J., “Probing Physics Students’ Conceptual Knowledge Structures through Term Association,” *Am.J.Phys*. (July 2002), p. 750 – 758.

Chabay, R., and Sherwood, B., “Bringing Atoms into First-Year Physics,” *Am.J.Phys*. (December 1999), p. 1045 – 1050.

Chabay, R., and Sherwood, B., *Matter and Interactions: Modern Mechanics*, (John Wiley & Sons Inc., New York, NY, 2002).

Chabay, R., and Sherwood, B., *Matter and Interactions: Electric and Magnetic Interactions*, (John Wiley & Sons Inc., New York, NY, 2002).

Champagne, A., Klopfer, L., and Anderson, J., “Factors Influencing the Learning of Classical Mechanics,” *Am J.Phys*. (December 1980), 1074 – 1079.

Chi, M.T.H., Feltovich, P.J., and Glaser, R., “Categorization and Representation of Physics Problems by Experts and Novices,” *Cognitive Science* 5 (1981), p. 121 – 152.

Clement, J., “Using Bridging Analogies and Anchoring Intuitions to Deal with Students' Preconceptions in Physics,” *Jour.Res.Sci.Teaching* 30:10, (1993), p. 1241 – 1257.

Crouch, C.H., and Mazur, E., “Ten Years of Experience and Results,” *Am.J.Phys*. (September 2001), p. 970 – 977.

Ehrlich, R., “How Do We Know if We Are Doing a Good Job in Physics Teaching?,” *Am.J.Phys*. (January 2002), p. 24 – 9.

Elby, A., “Helping Physics Students Learn How to Learn,” *Am.J.Phys*. Suppl. (July 2001), p. S54 – S64.

Halloun, I.A, and Hestenes, D., “The Initial Knowledge State of College Physics Students,” *Am J Phys*. (November 1985), p. 1043 – 1055.

Hammer, D., “Two Approaches to Learning Physics,” *The Physics Teacher* (December 1989), p. 664 – 670.

Hammer, D., “Student Resources for Learning Introductory Physics,” *Am J Phys*. (July 2000), p. S52 – S59.

Kim, E., and Pak, S., “Students do not Overcome Conceptual Difficulties after Solving 1000 Traditional Problems,” *Am.J.Phys*. (July 2002), p. 759 – 765.

McDermott, L.C., “What We Teach and What is Learned. Closing the Gap,” *Am J Phys*. (April 1991), p. 301 – 315.

McDermott, L.C., “Physics Education Research–The Key to Student Learning,” *Am.J.Phys.* (November 2001), p. 1127–1137.

McDermott, L.C., and Redish, E.F., “Resource Letter: PER 1: Physics Education Research,” *Am.J.Phy*. (September 1999), p. 755 – 767.

McKeechie, W.J., and Gibbs, G., *Teaching Tips : Strategies, Research, and Theory for College and University Teachers*, 10th Edition, (Houghton Mifflin, Boston, MA, 1999).

Mestre, J, “Learning and Instruction in Pre-College Physical Science,” *Physics. Today* (September 1991), p. 56 – 62.

Moore, T., and Schroeder, D., *Six Ideas that Shaped Physics*, (WCB/McGraw-Hill, Columbus, OH, 2003).

Redish, Edward F., “Implications of Cognitive Studies for Teaching Physics,” *Am.J.Phys*. (September 1994), p. 796 – 803.

Redish, E.F., “Millikan Lecture 1998: Building a Science of Teaching Physics,” *Am.J.Phys*. (July 1999), p.562 – 573.

Redish, E.F., *Teaching Physics with the Physics Suite*, (John Wiley & Sons Inc., New York, NY, 2003).

Reif, F., “Teaching Problem Solving–A Scientific Approach,” *The Physics Teacher* (May 1981), p. 310 – 316.

Reif, F., and Scott, L.A., “Teaching Scientific Thinking Skills: Students and Computers Coaching Each other,” *Am.J.Phys*. (September 1999), p. 819 – 831.

Reif, F., “Scientific Approaches to Science Education,” *Physics Today* (November 1986), p. 11.

Swartz, C.E., and Miner, T.D., *Teaching Introductory Physics : A Sourcebook*, (Springer Verlag, New York, NY, 1996).

Tobias, S., and Raphael, J., *The Hidden Curriculum: Faculty-Made Tests in Science*, 2 vols., (Plenum, New York, NY, 1997).

Van Heuvelen, A., "Learning to Think Like a Physicist: A Review of Research-Based Instructional Strategies," *Am.J.Phys*. 59, (1991), p. 891 – 897.

Van Heuvelen, A., "The Workplace, Student Minds, and Physics Learning Systems," *Am.J.Phys*. (November 2001), p. 1139 – 1146.

Physics Organizations

Consider becoming a member of the American Association of Physics Teachers (AAPT), which caters to two-year and four-year colleges as well as research universities. The association publishes *The Physics Teacher* and *The American Journal of Physics*. (http://www.aapt.org)

American Institute of Physics (http://www.aip.org) publishes *Physics Today*.

American Physical Society (www.aps.org) publishes the *Physics Review* journals.

Materials and Equipment

The materials for the demonstrations suggested in this resource manual can be obtained from the companies listed below.

Arbor Scientific (http://www.arborsci.com/)

Carolina Science and Math (www.carolina .com)

Central Scientific (http://www.sargentwelch.com)

Edmund Scientific (http://www.edsci.com)

Educational Innovations, Inc. (http://www.teachersource.com)

Fisher Scientific (https://www1.fishersci.com/index.jsp)

Klinger Educational Products Corporation (http://www.KlingerEducational.com)

Learning Technologies, Inc. (http://www.starlab.com)

Pasco Scientific (www.pasco.com)

Physics Academic Software (http://www.webassign.net/pasnew/)

Sargent-Welch (http://www.sargentwelch.com)

Vernier Software and Technology (http://www.vernier.com)

Ztek Company – for multimedia products (http://www.ztek.com/)

Organization of the IRM

This *Instructor's Resource Manual* is organized by chapters from the textbook. Each chapter in the manual starts with an outline, a summary of the major ideas discussed in the textbook, and a list of major concepts, followed by a brief paragraph on teaching suggestions and demonstrations. The manual then discusses, by sections, the important aspects that need to be emphasized, points out typical student misconceptions, and offers suggestions for demonstrations. Each chapter of the resource manual also has a list of transparency acetates, Physlet Illustrations, Physlet Explorations, Physlet Problems, appropriate selections from the student edition of *Ranking Task Physics*, and a list of end-of-chapter problems with solutions in the *Student Study Guide*. The chapters end with a selection of articles (from physics journals) on the topics covered in that particular chapter.

I would like to thank Christian Botting and Elizabeth Klug of Prentice Hall for their help, support, and encouragement while writing this manual.

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Chapter 1: Tooling Up

Outline

Summary

Chapter 1 is an overview of the nature of physics and the tools needed to understand the physical laws discussed in the rest of the textbook. It discusses the **fundamental physical quantities** of length, mass and time and their **units**. The conversion from one system of units to another is illustrated. The importance of accuracy in measurements and **significant figures** is shown. **Dimensional analysis** and **order of magnitudes** are discussed. The last section of this chapter is devoted to the understanding of **vectors, vector addition** and **subtraction** and how to break up vectors into **components**.

Major Concepts

- Background
    - Descriptive and predictive theories
    - Scientific method
    - Hypothesis
    - Scales

- Representation of numbers
    - Powers of ten
    - Standard scientific notation

- Fundamental physical quantities
    - Length, time and mass
    - SI system of units: meter, second and kilogram
    - cgs system
    - British engineering system
    - Unit prefixes

- Units and unit conversions
    - Fundamental units
    - Derived units
    - Conversion from one system to another

- Uncertainty in measurement
    - Uncertainty
    - Percentage uncertainty
    - Significant figures

- Dimensional analysis
  - Three primary dimensions
  - Matching dimensions
  - Deriving relations between physical quantities

- Estimates
  - Order of magnitude

- Scalars and vectors
  - Definition of scalars
  - Definition of vectors
  - Displacement vector
  - Addition and subtraction of vectors
  - Resultant vector
  - Commutative rule for vector addition of vectors
  - Null vector
  - Scalar multiplication of a vector
  - Unit vector
  - Components of a vector

Teaching Suggestions and Demonstrations

While many teachers prefer to skip the introductory chapter, it is worth the time spent if only to show the students the importance of understanding the basics in order to appreciate the physical laws they will be introduced to throughout the rest of the course. This is a good opportunity to stress the concept of **units**, **accuracy in measurement** of physical quantities and the basics of **vector mathematics**.

Sections 1-1 – 1-3

Not much time needs to be devoted to the concept of the **scientific method** except to point out the basic differences between hypothesis and predictive and descriptive theories. The idea of the scale of things will help students to relate to the behavior of things (in the physical world) from an atomic as well as universal point of view. Most students will be familiar with the three **fundamental quantities** of length, mass, and time. However, they need to be made aware of the order of magnitude of these quantities, which are shown in the corresponding tables. **Unit prefixes** is another aspect that students will tend to ignore unless mention is made of this in the class. **Conversion of units** is always a stumbling block to a fair number of students as is the need to keep track of significant figures. Tell students that the number of digits displayed on their calculators has nothing to do with the accuracy of the answer.

➲ **DEMO** *The Powers of Ten* is a ten-minute video film from Ztek Company that shows the scale of things starting from our own backyard and going “out to the edges of the universe and in to the micro world of cells, molecules, and atoms”. This is a good film that never fails to grab the students’ attention.

Sections 1-4 – 1-5

Dimensional analysis is useful when checking the validity of an equation as well as when deriving relations between physical quantities. It also is a very helpful tool when a student is not sure of the units for a particular physical quantity in a calculation. Worked example 1-6 is a good exercise to go over in class. While it is not necessary to spend a great deal of class time on **estimating** exercises, it is a good idea to stress the importance of checking the order of magnitude of an answer to see if it is indeed a reasonable value.

Section 1-6

A sound understanding of **vectors** and their mathematical manipulations is absolutely essential if the student is to grasp two- and three-dimensional physics. This chapter introduces just the displacement vector. However, tell the students to expect many more vector physical quantities as the semester progresses. In finding **components of vectors**, students will associate the cosine factor with the *x*-component of the vector. They will fail to recognize that this will depend on the angle used. They will also not notice the difference between using angles measured counterclockwise from the positive *x*-axis and those measured clockwise from the negative *x*-axis. It might be well worth the time spent in reminding them of the sign of the components based on the quadrant in which the vector is located.

➲ **DEMO** Use meter sticks of varying lengths to introduce vectors and vector addition/subtraction. These can be easily built by attaching small triangular pieces of light weight wood to one end of the stick. This will be the head of the vector and the other end will serve as the tail. To make it more visible to the entire class, paint the meter stick in two different and bright colors at 10-cm intervals. If you use a white board, make these meter sticks magnetic by attaching magnetic strips to their underside.
This then becomes an easy tool to illustrate addition and subtraction of vectors by the head-to-tail or the parallelogram method.

➲ **DEMO** *Video Encyclopedia of Physics Demonstrations* Disc (by The Education Group) is a laser disc that shows how vectors can be broken down into components along the coordinate axes.

Textbook Resource Information

Transparency Acetates

Fig. 1-13	Addition of two vectors by graphical method
Fig. 1-14	Adding three vectors
Fig. 1-16	Negative of a vector
Fig. 1-17	Vector difference
Fig. 1-20	Position vector and resultant of two displacements
Fig. 1-21	Components of a vector in two-dimensional representation
Fig. 1-25	Components of a vector in three-dimensional representation

Physlet Physics Illustrations

1.1 Introduction to Physlets
1.2 Animations, Units and Measurements
3.1 Vector Decomposition

Physlet Physics Explorations

1.1 Click-Drag To Get Position
1.2 Input Data Numbers
3.1 Addition of Displacement Vectors

Physlet Physics Problems

1.1 Measurements
3.1 Vector Components
3.2 Addition of Two Vectors

End of Chapter Problems with Solutions in the *Student Study Guide*

5, 13, 19, 31, 53, 61

Suggested Readings

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Notes and Ideas

Preparation time: *Estimated:* ____________ *Actual:* ____________

Class time spent on material: *Estimated:* ____________ *Actual:* ____________

Related laboratory activities:

Demonstration materials:

Notes for next time:

Chapter 2: Straight-Line Motion

Outline

Summary

One-dimensional kinematics is the study of motion in a straight line. Chapter 2 gives a working definition of the main concepts of one-dimensional kinematics; namely, **displacement**, **speed**, **velocity** and **acceleration**. The emphasis is on motion with constant acceleration. The kinematic **equations of motion** are derived and **motion graphs** are discussed. The chapter also treats **free fall motion,** which is one-dimensional vertical motion under the influence of the gravitational force. Finally, **displacement**, **velocity** and **acceleration** are discussed using the calculus of integration.

Major Concepts

- Displacement
  - Distance and displacement
  - Position vector
  - Displacement vector
  - Net displacement
  - Distance-time graph

- Velocity
  - Speed and average speed
  - Difference between speed and velocity
  - Average and instantaneous velocity
  - Motion graph

- Acceleration
  - Average and instantaneous acceleration
  - Kinematic equation for constant acceleration motion

- Freely falling objects
  - Acceleration due to gravity
  - Free fall
  - Equations of motion for freely falling objects

- Integration and motion in one dimension
  - Displacement as time integral of velocity
  - Velocity as time integral of acceleration
  - Equations of motion using integration

Teaching Suggestions and Demonstrations

You will find that students are familiar with words such as **speed** and **acceleration** because of their experiences with driving a car. However, they will not be aware of the more formal physics definitions of these terms or the differences between **speed** and **velocity** or **distance** and **displacement**. Hence they have a lot of misconceptions. It will be a good idea to take the time to lay the groundwork for understanding **two-** and **three-dimensional** motion. This is also the first time they will have a chance to learn **problem-solving methods**, which are an integral part of any physics course.

Sections 2-1 – 2-3

Students who have had physics in high school will be familiar with **speed** and **velocity** or **distance** and **displacement**. However, the majority of the students will not have had physics prior to this class. Since they were introduced to vectors in Chapter 1, discuss the difference between these quantities in terms of **scalars** and **vectors**. The concept of the **position vector** is a difficult one for most students. Use the vector meter sticks to show them the **position vectors** and the **displacement** vector due to the change in the position of an object.

Emphasize that **displacement** is the change in the position of an object and not the actual distance covered. Take the example of a typical day in the life of one of your students. Ask them to estimate how much they walk and/or drive in a day from the time they get up in the morning to the time they go to bed at night. Then ask them what their **displacement** would be for such a day. They will then see that the **displacement** is zero while the distance covered is not.

The difference between **speed** and **velocity** will have to be explained with examples. Take the case of a person running laps around a track. Ask the students to determine the **speed** and the **velocity** given the number of laps covered in a given time.

In discussing **acceleration**, be sure to spend a little time on the units. This can be confusing since the denominator has two time units.

Motion graphs are a source of confusion and frustration. Students have a hard time visualizing **negative velocity** or **negative acceleration** as well as change in the direction of motion as represented on a graph. They will need lots of practice in interpreting **motion graphs**. While they have been introduced to the concepts of slope and tangent to a curve in calculus, don't be surprised if most of the students fail to make the connection here when studying **displacement** vs**. time** or **velocity** vs. **time** graphs.

➲ **DEMO** Use the vector meter sticks described in Chapter 1 of this manual to show that the displacement vector is the subtraction of two position vectors.

➲ **DEMO** A motion detector (from Pasco or Vernier Software) is a good way to show, in real time, the position, velocity and acceleration versus time of a student volunteer moving in front of the motion detector. Have a student walk toward and away from the detector. You can either show the graphs directly on the monitor screen or save them for later use. Make sure the path the student will walk is clear, so no one trips. The motion detector is very small, so care must be taken to not damage it.

Section 2-4

Students will have a difficult time with the concepts of **constant velocity** and **constant acceleration**. Quite often they will confuse one with the other. Use the familiar example of driving a car on the highway with the cruise control activated to discuss constant velocity. Use one of the demos listed here to clarify the difference between **constant velocity** and **constant acceleration**.

Some people prefer to skip the derivations of the **kinematic equations** for **constant acceleration**. This is a question of philosophy and availability of class time. If you decide to skip the derivations, be sure to discuss the fact that these equations are derived from the basic definitions of **displacement**, **velocity** and **acceleration**. Students will have a difficult time interpreting the problems and assigning symbols to the various values given in a problem. They will need plenty of practice, and the textbook has sufficient worked examples. In **solving problems**, students will benefit greatly from sketching the situation however simple it may be. Unfortunately, they will be reluctant to do this.

- ➲ **DEMO** Use Pasco air track and gliders. The track should be set and leveled before use. Turn on the power for the air supply and adjust the flow until the carts just start to rise on the jets of air. The carts will move with constant velocity. You can have two students help you to measure the time taken for the glider to cover equal distances. This is an excellent demonstration for showing constant velocity. You will find that the blower is a little loud, so you will have to talk over it.

- ➲ **DEMO** Use the same set up as above. Raise the air track by placing aluminum blocks under a single leg of the air track. The glider will move down the incline with constant acceleration. You can show that the velocity is not constant by having two students measure the time taken to cover equal distances as the glider moves down the incline. Alternately, a motion detector can be used to measure acceleration with the Pasco Dynamic Carts.

Section 2-5

Making the transition from **constant acceleration** motion in the horizontal direction to **free fall** will be fairly easy. There are two points that will confuse most students with regard to the value and direction of *g*. You will have many students claim that *g* will be zero at the very top of a vertical motion since the velocity goes to zero there. Remind them that acceleration is the change in velocity (direction as well as magnitude). So, if the velocity is 10 m/s just before it reaches the very top and it is 10 m/s a moment later on its way down, then the acceleration is (-10-10)/2, which is a non-zero quantity.

Students will also have to be constantly reminded that the *g* vector is always in the downward direction regardless of the direction of motion of the object in **free fall**.

- ➲ **DEMO** Simultaneously drop a book and a sheet of paper from the same height. The book falls much faster. Crumple the paper into a ball and repeat the experiment, and the two will reach the floor at almost the same time. Discuss the effect of air resistance on “light” objects that have a larger surface area.

- ➲ **DEMO** You could illustrate the same concept using the penny and feather equipment (from Central Scientific). Make sure the lead ball and feather are at one end of the tube, which is filled with air. Quickly bring the tube to a vertical position, and you will see the ball falling much faster than the feather. Now connect the tube to a vacuum pump. Once the air is pumped out, close the valve and disconnect the tube. Now repeat the experiment and you will find the ball and feather reaching the bottom simultaneously.

➲ **DEMO** This is a simple demo to calculate the value of g by using the equation: $x = ½ gt^2$
Have one student hold a meter stick vertically. Have a second student hold his/her fingers (beside the 50-cm point) on either side of the stick as if ready to grab it. At some random time the first student drops the meter stick. The second student should try to grab the meter stick the instant he/she sees it being dropped. Measure the distance from the 50-cm mark to the point where it is caught. Use the equation to calculate g.
You could do this as a demo in front of the whole class or have students pair up and do it as an in-class activity. This can also be used to discuss reaction time of the student.

Section 2-6

This is a good time to show the students the application of calculus to situations in physics. Many of your students will be able to integrate a function with ease if the function uses x and y as the variables. However, the moment you give them an equation expressing **velocity** as a **function of time**, they will flounder when asked to find the **displacement**. This section also deals with the case of **non-constant acceleration** and discusses what happens when the **acceleration** is indeed constant.

Textbook Resource Information

Transparency Acetates

Fig. 2-2	Distance vs. time graph
Fig. 2-3	Position-time graph
Fig. 2-5	Slope of displacement-time graph
Fig. 2-9	Velocity-time and acceleration-time graphs
Fig. 2-19	Time sequence picture of a ball in free fall
Fig. 2-25	Displacement as area under velocity-time curve
Fig. 2-26	Velocity as area under acceleration-time curve

Physlet Physics Illustrations

2.1 Position and Displacement
2.3 Average and Instantaneous Velocity
2.4 Constant Acceleration
2.5 Motion on a Hill
2.6 Free Fall

Physlet Physics Explorations

2.1 Compare position vs. time and velocity vs. time graphs
2.2 Determine the correct graph
2.7 Determine the area under $a(t)$ and $v(t)$

Physlet Physics Problems

2.2 Analyzing motion

2.3 Graph matching
2.11 Analyzing position-time graph
2.18 Free fall
2.19 Free fall

Ranking Task Exercises in Physics, Student Edition

Page 1, 3	Motion diagrams – velocity
Page 2, 4	Motion diagrams – acceleration
Page 5	Acceleration of objects in different situations
Page 6, 7	Free fall
Page 8	Position time graph – displacement
Page 9	Change in velocity
Page 10	Position time graph – average speed
Pages 11, 12	Motion diagrams

End of Chapter Problems with Solutions in the *Student Study Guide*

9, 21, 35, 59, 65, 73

Suggested Readings

Aguirre, J.M., “Student Preconceptions about Vector Kinematics,” *The Physics Teacher* (April 1988), p. 212 – 216.

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Trowbridge, D.E., and McDermott, L.C., "Investigation of Student Understanding of the Concept of Velocity in One Dimension," *Am. J. Phys*. (December 1980), p. 1020 – 1028.

Trowbridge, D.E., and McDermott, L.C., "Investigation of Student Understanding of the Concept of Acceleration in One Dimension," *Am. J. Phys*. (March 1981), p. 242 – 253.

Notes and Ideas

Preparation time: *Estimated:* ____________ *Actual:* ____________

Class time spent on material: *Estimated:* ____________ *Actual:* ____________

Related laboratory activities:

Demonstration materials:

Notes for next time:

Chapter 3: Motion in Two and Three Dimensions

Outline

Summary

Chapter 2 dealt with the kinematics of **linear motion**. Now, in Chapter 3, these concepts are extended to motion in **two** and **three dimensions**. The **position**, **velocity** and **acceleration vectors** for **three-dimensional motion** are defined in terms of their components and, in particular, for the case of **constant acceleration** motion. This leads into the discussion of **projectile motion** in the absence of air resistance, as well as **circular motion**, which is motion in a plane. **Relative velocity** is discussed in the last section of the chapter.

Major Concepts

- Motion in two and three dimensions (in a plane and in space)
    - Position and displacement vectors
    - Velocity and acceleration
    - Graphical representation of trajectories

- Motion with constant acceleration
    - Plane of motion
    - *x* and *y* components of position vector
    - *x* and *y* components of velocity vector

- Projectile motion
    - Projectile motion as two independent motions in horizontal and vertical planes
    - Trajectory of projectile motion
    - Range
    - Flight time
    - Maximum height

- Uniform circular motion
    - Definition of the radian
    - Plane polar coordinates
    - Angular speed and its relation to linear speed
    - Period and frequency
    - Centripetal acceleration and its relation to angular velocity

- Relative motion
    - Frame of reference
    - Relative velocity

Teaching Suggestions and Demonstrations

Many of the topics covered in Chapter three are extensions of the ideas that were introduced in the previous chapter, with the exception of **circular motion** and **relative velocity**. This chapter also uses vectors extensively. The concept of treating **two-dimensional motion** as two independent motions in two perpendicular directions will baffle many students. Allow sufficient time to work examples in class. Also consider using simulations as demos or as in-class activities. There are plenty of these available, and these are listed under resources.

Sections 3-1 – 3-2

These two sections discuss the trajectory for motion in a plane. It may be helpful to quickly review vector addition. This will make it easy to understand what follows in this chapter. Stress the difference between **position vectors** and the actual trajectory of motion. Students will calculate the **acceleration** for a given situation where the speed (magnitude of **velocity**) changes without much difficulty. However, they will not as easily be able to visualize the **acceleration** vector for motion with directional change as well. Use the tail-to-head method of vector addition to show that the **displacement vector** is $\Delta\vec{r}$, and the **acceleration vector** is obtained by finding $\Delta\vec{v}$ as the difference between two **velocity vectors** for a small time interval Δt.

Figure 3-6 is a good one to show the **velocity** and **acceleration** vectors at a point on the trajectory of motion. Discuss the fact that the **speed** of the object changes because of the **acceleration** component parallel to the trajectory at that point, and the directional change is brought about by the component of the **acceleration** that is perpendicular to the path. These two will change in direction and magnitude as the object moves along its trajectory.

➲ **DEMO** Use the vector meter sticks described in Chapter 1 of this manual to show the displacement and acceleration vectors. Draw a random trajectory on the board. Pick two points Δt apart on the path. Use the vector meter sticks to represent v_1 and v_2. Show that $v_2 - v_1$ vector gives the direction of the acceleration vector.

Sections 3-3 – 3-4

Begin by discussing how the **kinematic equations** derived in Chapter 2 can be used in the x and y directions independent of each other. Then show what happens to these equations when there is **constant velocity** in the horizontal direction and **constant acceleration** g in the vertical direction. This particular section lends itself nicely to the use of examples from sports, especially when discussing **range** and **time of flight** of a **projectile**. Students will relate well to these examples.

The significance of Equation 3.39 will not be obvious to the students. You may have to elaborate on the fact that there will be two angles for which the range will be the same. Figure 3-9 clearly shows the **velocity** component changing in the downward direction and being constant in the horizontal direction. Discuss this in detail and point out that while v_y,=0, the object still has a **velocity** in the x direction, and this is what makes it go forward as it experiences **free fall** in the vertical direction.

Some of the difficulties encountered by students include using $a = g$ in the x direction motion, not recognizing that there will be an **acceleration** at the highest point of the trajectory, even though v_y,=0, and not knowing how to use the solution from the y direction motion to find the unknown in the x direction or (vice versa). Work as many examples of different situations as possible in class.

➲ **DEMO** The Monkey and Hunter demonstration (from Pasco Scientific) shows that vertical and horizontal motion are two independent motions. A ball is launched from a cannon, and simultaneously the target is released from the magnet from which it is suspended. (A small piece of permanent magnet holds the target in place. When the ball is launched, this sends a pulse of current that disrupts the field). The horizontal motion is at constant velocity, and both objects have the same constant acceleration in their vertical motion. So by aiming directly at the target, you will successfully hit the target. It might be a good idea to set up the demo and have it aimed correctly before the start of class.

➲ **DEMO** A Pasco projectile launcher can be used to test the range of the projectile for different angles of projection. This is a good demo to show that the maximum range can be obtained for a launching angle of 45^o.

➲ **DEMO** Simultaneous ball drop. This can be either built or purchased from Central Scientific. Two balls are situated on a small platform. When the spring is released, one ball falls vertically down and the other is launched with a horizontal velocity.

Section 3-5

Most of your students will be familiar with the **radian** unit. But it might be a good idea to go over the conversion from **degrees** to **radians** to **revolution** and why the **radian** is a dimensionless quantity. Stress that in converting **linear velocity** to **angular velocity** and vice versa, ω has to be in rad/s. This would be a good place to remind them of **dimensional analysis** and why other units like deg/sec or rpm will not work.

Go back to Fig. 3-6 and discuss the fact that for **uniform circular motion** there is no **acceleration** in a direction parallel to the path of motion. Then show them Fig. 3-22, which clearly illustrates the existence of a **radial acceleration** for an object moving with **constant speed** in a circular path. Also emphasize that while the magnitude of the **position vector** $\vec{r}$, **velocity** $\vec{v}$ and **acceleration** $\vec{a}$ are constant, they are continually changing in direction.

Section 3-6

This will be the first time that most of your students are introduced to the formal definition of frame of reference. Start off the discussion with the demo described below. Then discuss the fact that all motion is **relative** and depends on the **reference frame** with respect to which it is described. Figure 3-28 and worked example 3-13 explain this concept very clearly.

➲ **DEMO** Walk across the room at a steady rate. Toss a ball in a parabolic path at the start of your motion and catch the ball at the end of your motion. This might take a little practice. If done correctly, from your frame of reference the ball goes vertically up and then down. From the students' frame of reference the ball has a parabolic trajectory.

➲ **DEMO** Alternately, stand on a platform with wheels. Have another person pull you with constant velocity to simulate a moving frame of reference. Toss a ball straight up and catch it. This demo should be done with great care. If the person pulling the platform jerks on it, you can fall back. For the same reason, it is best that a student does not perform the demo.

➲ **DEMO** A battery operated toy tractor and a large sheet of paper are all you need for this simple but effective demonstration of relative velocity. The tractor is placed at an angle near one edge of the sheet of paper. Activate the tractor and pull the sheet of paper at a constant rate. This will simulate a running "river". Practice this before class so that you can get the tractor to end up on the other side of the river but at the same relative place it was to begin with.

Textbook Resource Information

Transparency Acetates

Fig. 3-2	Position and displacement vectors
Fig. 3-6	Velocity and acceleration vectors represented in terms of components
Fig. 3-8	Plane of motion for a projectile
Fig. 3-9	Horizontal and vertical components of velocity vector for a projectile
Fig. 3-12	Range and relative height of a projectile for different launch angles
Fig. 3-22	Computing direction of Δv
Fig. 3-23	Computing direction of Δv
Fig. 3-25	Instantaneous position, velocity and acceleration
Fig. 3-28	Velocity in two frames of reference

Physlet Physics Illustrations

3.1 Vector Decomposition
3.3 Direction of Velocity and Acceleration Vectors
3.4 Projectile Motion
3.5 Uniform Circular Motion and Acceleration
3.6 Circular and Noncircular Motion

Physlet Physics Explorations

3.4 Space probe with constant acceleration
3.5 Uphill and downhill projectile motion
3.6 Uniform circular motion

Physlet Physics Problems

3.3 Motion down an incline
3.5 Graphing position and velocity graphs
3.6 Analyzing two-dimensional motion
3.10 Relation between initial velocity and launch angle
3.15 Circular motion
3.17 Speed and acceleration in circular motion

Ranking Task Exercises in Physics, Student Edition

Page 47	Rifle shots – time to hit ground
Page 48	Toy trucks rolling off table