LABORATORY MANUAL WITH COMPUTER ACTIVITIES

JONES/CHILDERS

CONTEMPORARY COLLEGE PHYSICS

2ND EDITION

PAUL ROBINSON

BULLARD HIGH SCHOOL
FRESNO, CALIFORNIA

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In addition to computer software, some of the labs in this manual refer to equipment available from commercial vendors. For convenience, a list of the equipment recommended in the manual follows each vendor. Specific references are made only if, based on the personal experience of the author, they are preferable to other commercially available versions. Contact the vendor for current price and catalog information.

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About the Author

Paul Robinson has been teaching physics since 1974 after getting his BA in Physics at the University of California, Santa Barbara. He completed his MA in Physics at Fresno State University in 1984. Despite his enthusiasm for teaching physics, he quickly realized his love for physics was not a universal sentiment. While looking for new and innovative ways to lure students into his classroom at a teachers' conference during his first year of physics teaching, he met Paul Hewitt. Hewitt's fresh approach to physics was at the time considered controversial because it emphasized thinking about the ideas of physics instead of doing computational physics problems.

Meeting Hewitt encouraged Robinson. His first teaching assignment was in Los Banos, California—a rural community whose students had a low interest in physics. In 1978, Robinson invited Hewitt to be a guest lecturer in his classes. At the conclusion of each lecture, Robinson laid between two beds of nails as Hewitt crushed a large concrete block upon Robinson's chest with a sledge hammer. By the end of the day, people from all over town were coming to see this dramatic demonstration. Enrollments soared!

In 1983, Robinson was recruited to assist with the design and opening of Edison Computech—a magnet science, computer, and math school for grades 7–12 in Fresno. Encouraged by the administration to be innovative, a conceptual physics course was put at the *beginning* of the science sequence instead of at the *end*. Despite nearly 100 years of tradition to the contrary, this approach is now gaining nation-wide acceptance.

In 1987, Robinson received the Presidential Award for Excellence in Science Teaching. He has also received the Distinguished Service Citation from the Northern California Section of the *American Association of Physics Teachers* and was the first high school teacher elected president of that assocation. He and his former student, Jay Obernolte, have developed computer software to accompany Robinson's lab manuals. In 1990, Robinson took a leave of absence to be a guest lecturer at American River College in Sacramento and now teaches at Bullard High School in Fresno, California, where he teaches three levels of physics.

Preface

> "In the matter of physics, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than 20 formulae extracted from our minds; it is particularly important that a young mind that has yet to find its way about in the world of phenomena should be spared from formulae altogether. In his physics they play exactly the same weird and fearful part as the figures of date in Universal History."
>
> —Albert Einstein

This manual is intended to serve as the laboratory component for a first-year college, non-calculus physics course or a high school advanced placement physics course. Many of the labs have been used by the author with both community college and high school students. A typical three-hour college lab session often makes it possible to schedule more than one lab in a given session. This may be especially desirable when special equipment or computers are in short supply and all students cannot do the same lab at the same time.

Use of the Computer

Only four of the labs in this manual are purely computer activities, but over half of the forty-six labs can involve the use of the computer either as a laboratory instrument or graphing tool. Your students' level of involvement with the computer will depend on the availability of hardware and your discretion.

The computer is a powerful tool for collecting and analyzing data and displaying it graphically. Programs such as *Data Plotter* enable students to input data easily and to plot the corresponding graph in minutes. With the computer, students can plot more graphs in less time and include printouts of the graphs in their lab reports. The computer can also help students analyze their data quickly and efficiently. The result is a shift of focus—students can spend more time interpreting their graphs and studying the relationships between variables and less time manually plotting data.

With the appropriate hardware, the computer can also be used as a laboratory instrument to measure time and temperature, sense light, detect the presence of radioactive particles, and make real-time plots of distance vs. time (when used with a sonic ranger). Use of the computer as a laboratory instrument is noted as an option in all appropriate labs in this manual.

If you have access to a computer lab, you may want to have students save their data on disk and graph it later in the computer lab, where computers and printers are more readily available. Likewise, some of the labs involving simulations may be done in the computer lab.

Much of the software and many of the computer-related peripherals for the Apple II Series computer used in this lab manual have been developed by Laserpoint. In most cases, other commercially available software programs and hardware systems can be substituted for the comparable Laserpoint product.

Institutions officially adopting this lab manual are entitled to a package discount on Laserpoint software and hardware. Currently available are:

LabKit
Interfacing hardware and software for timing, temperature, and light sensing. Includes *LabTools* interfacing software and *Data Plotter* graphing software. *LabTools* includes the "Chronometer," "Thermometer," "Period of a Pendulum," "Acceleration of Gravity," "Light Meter," and "Super Sonic" programs.

Super Sonic Plus
Ultrasonic ranging system and software. Includes sonic ranger, dual-function connector, and *Super Sonic Plus* software.

Laboratory Simulations & Good Stuff
Student lab simulation software. Programs include "Race Track," "Tail-gated by a Dart," "Flat as a Pancake," "Extra Small," "Wrap Your Energy in a Bow," "Solar Equality," "Nuclear Marbles," "Thin Lens," "Radiating Dipole," Moving Charge," "Maxwell's Demon," "Doppler Effect," "Longitudinal Waves," "Sum of Two Waves," "Chain Reaction," "Free Particle," "Music," and "Life."

SuperSims-I
Student lab simulation software. Includes "Sharp Shooter," "Falling Around," "Bull's Eye," "Impact Speed," and "Nuclear Marbles."

Also available is clip art entitled *Hewitt Drew It* and *The Art of Physics* as well as test generation software and test banks for both the Macintosh and IBM computers. For more information, write or call: Laserpoint, 1328 W. Palo Alto Ave., Fresno, CA 97311, (209) 435-5273, or FAX (209) 449-9760.

Laboratory Investigations

The forty-seventh lab in this manual is not one, but several ideas for open-ended experimentation with physics concepts. These open-ended investigations may be assigned at the close of each major topic area, as a mid-term "break," or as an ongoing term project.

Equipment and Software Vendors

In addition to computer software, some of the labs in this manual refer to equipment available from commercial vendors. For convenience, a list of the equipment recommended in the manual follows each vendor.

PASCO Scientific Co.
10101 Foothills Blvd.
P.O. Box 619011
Roseville, CA 95661
(800) 772-8700

Atwood's pulley, force tables, low-friction pulleys, air track, current balance, CASTLE Kit, electrical equivalence of heat apparatus, LabNet Geiger interface.

Arbor Scientific
P.O. Box 2750
Ann Arbor, MI 48106-2750
(800) 367-6695
Genecons, Nichrome wire apparatus, parallel bulb apparatus, spare bulbs, parallel protractor, balances, digital stop watches, lasers.

SciMaTech
588 Cambridge Ave.
Palo Alto, CA 94306
(800) 525-5344
Colliding pendula apparatus, polar plot grapher paper, force table and pulleys, vector laboratory.

Sargent-Welch Scientific Co.
7300 North Linder Avenue
P.O. Box 1026
Skokie, IL 60077
(312) 677-0600
Loop-the-loop apparatus.

Bernard O. Beck Company
P.O. Box 272
Arlington, TX 76004-0272
Ballistic pendulum apparatus, centripetal force apparatus.

HelpWare Educational Materials
54 Charlotte Avenue
Hamburg, NY 14075
(716) 649-1493.
Physics Lab Help-Ware.

Vernier Software
2920 S.W. 89th Street
Portland, OR 97225
(503) 297-5317
Voltage Plotter and Voltage Input Unit, as well as other excellent interfacing and simulation software.

Acknowledgements

Nobody I have ever heard of writes a lab manual with this many ideas from scratch. Most of my ideas came from other teachers who shared their ideas at the *American Association of Physics Teachers* (AAPT) meetings I have attended since my first year of teaching. This sharing of ideas and cooperative spirit is a hallmark of our profession.

Many more individuals have contributed their ideas and insights than possibly can be mentioned here. I am grateful to all of them, and would like to thank especially Chuck Hunt, Scott Perry, Ann and John Hanks, Bill Papke, and Lowell Christensen of American River College, who generously shared so many of their ideas with me so freely; Sheila Cronin, Avon High School (Connecticut), for her adaptions of CASTLE curriculum material; Douglas Jenkins, Warren Central High School (Kentucky), for his creative ideas; Michael Zender, California State University, Fresno, and Brian

Holmes, California State University, San Jose, for their technical assistance; and Frank Crawford, University of California, Berkeley, and Verne Rockcastle, Cornell University, for their inspiration.

For reading and critiqueing my manuscript, I would like to thank John Hubisz, College of the Mainland, Al Bartlett, University of Colorado, Paul Hickman, Belmont High School (Massachusetts), and John Fitzgibbons, Cazenovia High School (New York). Thanks also to Dave Griffith and Paul Stokstad of PASCO Scientific for their professional assistance.

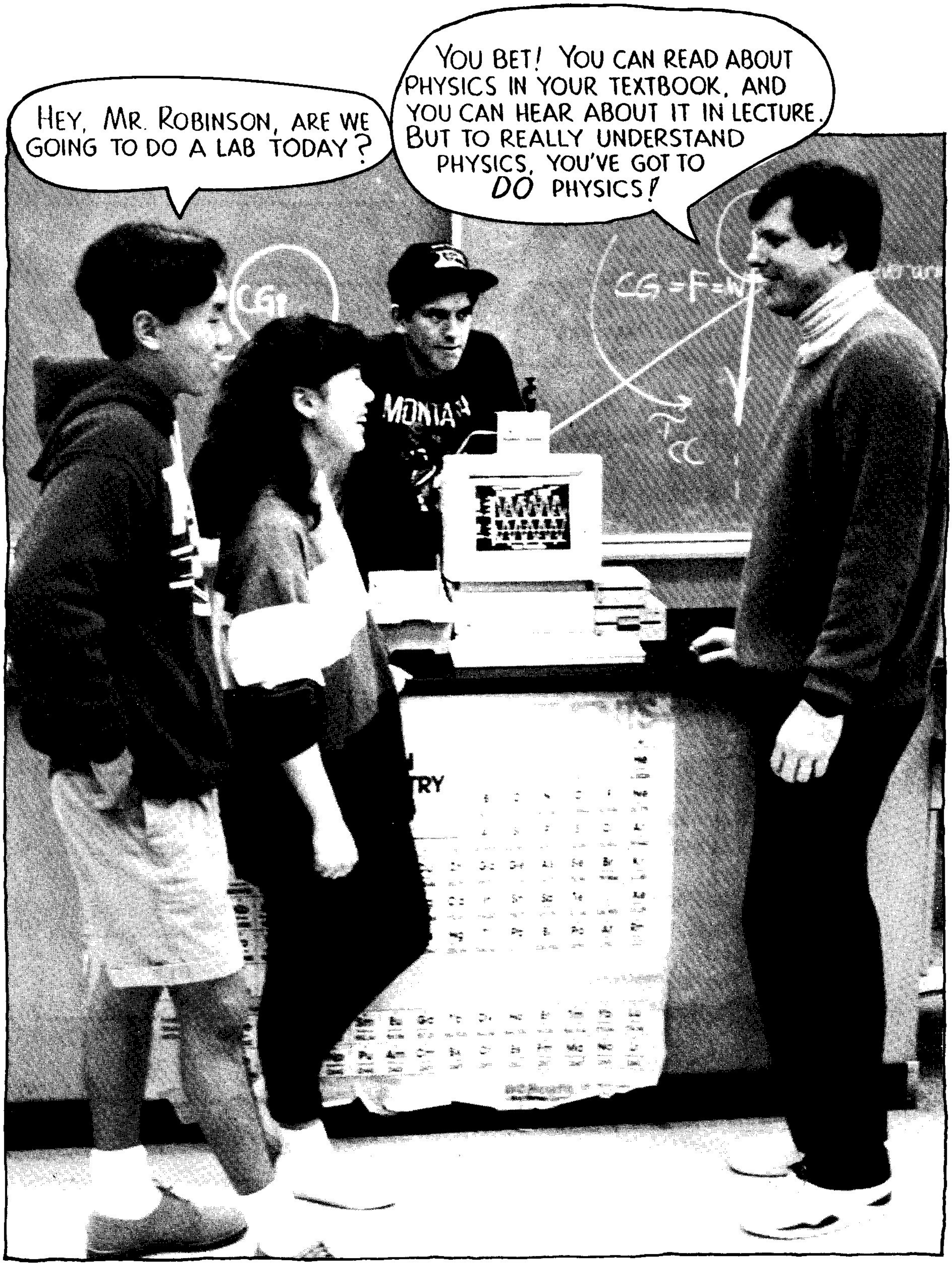
My AAPT colleagues, Robert H. Good, California State University, Hayward, and Dave Vernier of Vernier Software were a tremendous help to me with their suggestions on the best ways to integrate the computer in the physics laboratory. My thanks to them and to Lester Evans, Lexington, Kentucky, for his insightful suggestions on using the sonic ranger. I am especially indebted to my talented programmer and former student, Jay Obernolte, for developing software to accompany this manual.

And thanks to my parents and children—David, Kristen, and Brian—for being so patient!

Most of all, I would like to express my gratitude to my mentor Paul Hewitt—not only for his illustrations, but for his optimism and support, which have been a constant source of inspiration throughout my career.

Paul Robinson
Fresno, California
October 1992

Contents

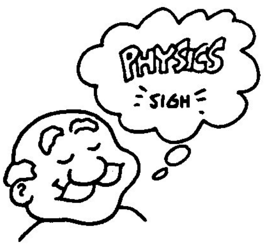

HEY, MR. ROBINSON, ARE WE GOING TO DO A LAB TODAY?
YOU BET! YOU CAN READ ABOUT PHYSICS IN YOUR TEXTBOOK, AND YOU CAN HEAR ABOUT IT IN LECTURE. BUT TO REALLY UNDERSTAND PHYSICS, YOU'VE GOT TO *DO* PHYSICS!

To the Student

Goals

The laboratory part of your physics course should:

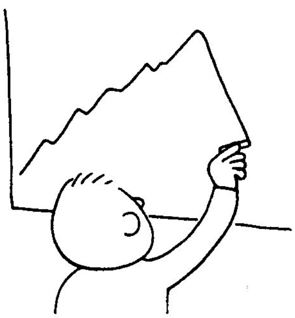
1) Provide you with hands-on experience that relates to physics concepts.
2) Provide training in making measurements, recording, organizing, and analyzing data.
3) Provide you with experiences in problem solving.
4) Provide you an opportunity to design your own experiment.



This manual contains 46 labs designed to give you hands-on experience that relates to a specific concept and practice with a particular piece of apparatus. Generally, the labs involve acquiring data in a prescribed manner. You will make measurements, identify and estimate errors, organize, graph, and interpret your data. The last lab, entitled "You're On Your Own," suggests laboratory investigations that will give you experience designing and developing your own experimental procedure.

Physics is *much* more than memorizing formulas. Imagine trying to learn to swim without getting wet! By *doing* physics, you will understand—and *enjoy!*

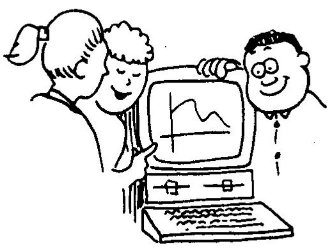
Graphing and the Use of the Computer



When you look at two columns of numbers that are related in some way, they probably have little meaning to you. A *graph* is a visual way to see how two quantities are related. You can tell in an instant what the stock market has been doing by glancing at a plot of the Dow Jones Industrial Average plotted as a function of time. Graphing is a important analytical tool, particularly when investigating how two quantities are related.

The computer is a powerful tool for collecting and analyzing your data and displaying it graphically. Programs such as *Data Plotter* enable you to input data easily and to plot the corresponding graph in minutes. Large or small printouts of your graphs can be can be added to lab reports. Energy that would have been used to make graphs can more wisely be invested in interpreting them—making you more productive.

Because of the computer's ability to calculate rapidly and accurately, it can greatly help you analyze data quickly and efficiently. You will be free to focus on the relationships between variables rather than the process of manually plotting the data.



In many of the labs in this manual, you will be encouraged to use the computer as a laboratory instrument that can measure time and temperature, sense light, detect the presence of radioactive particles, and make real-time plots of distance vs. time (when used with a sonic ranger). If you have the opportunity to use the computer as a lab instrument, you will see that it is an accurate and speedy data collector.

Lab Reports

Your instructor will provide you with specific instructions on how to prepare your lab reports. The general guideline for writing a lab report is: Could another student taking physics at some other school read your report and understand what you did well enough to replicate your work?

Suggested Guidelines for Lab Reports

Lab Number and Title Write your name, data, and section/period in the upper right-hand corner of your report.

Purpose Write a brief statement of what you were exploring, verifying, measuring, investigating, etc.

Method Make a rough sketch of the apparatus you used and a brief description of how you planned to accomplish your lab.

Data Show a record of your observations and measurements, including all data tables.

Analysis Show samples of calculations performed, any required graphs, and answers to questions. Summarize what you accomplished in the lab.

Safety in the Physics Laboratory

By following certain common-sense rules in the physics lab, you can make the lab safe not only for yourself but for all those around you.

1. Never work in the lab unless an instructor is present and aware of what you are doing.

2. Prepare for the lab activity or experiment by reading it over first. Ask questions about anything that is unclear to you. Note any cautions that are stated.

3. Dress appropriately for a laboratory. Avoid wearing overly bulky or loose-fitting clothing or dangling jewelry. Pin or tie back long hair, and roll up loose sleeves.

4. Keep the work area free of any books and materials not needed for hat you are working on.

5. Wear safety goggles when working with flames, heated liquids, or glassware.

6. Never throw anything in the laboratory.

7. Use the apparatus only as outlined in the manual or by your instructor. If you wish to try an alternate procedure, obtain your instructor's approval first.

8. If a thermometer breaks, inform your instructor immediately. Do not touch either the mercury or the glass with your bare skin.

9. Do not force glass tubing or a thermometer into a dry rubber stopper. The hole and the glass should both be lubricated with glycerin (glycerol) or soapy water, and the glass should be gripped through a paper towel to protect the hands.

10. Do not touch anything that may be hot, including burners, hot plates, rings, beakers, electric immersion heaters, electric bulbs. If you must pick up something that is hot, use a damp paper towel, a potholder, or some other appropriate holder.

11. When working with electric circuits, be sure that the current is turned off before making adjustments in the circuit.

12. If you are connecting a voltmeter or ammeter to a circuit, have your instructor approve the connections before you turn the current on.

13. Do not connect the terminals of a dry cell or battery to each other with a wire. Such a wire can become dangerously hot.

14. Report any injuries, accidents, or breakages to your instructor immediately. Also report anything you suspect may be malfunctioning.

15. Work quietly so that you can hear any announcements concerning cautions and safety.

16. Know the locations of fire extinguishers, fire blankets, and the nearest exit.

17. When you have finished your work, check that water and gas are turned off and that electric circuits are disconnected. Return all materials and apparatus to the places designated by your instructor. Follow your instructor's directions for disposal of any waste materials. Clean the work area.

Emergency Procedures

Report all injuries and accidents to your instructor immediately. Know the locations of fire blankets, fire extinguishers, the nearest exit, first aid equipment, and the school nurse's office.

Situation	Safe Response
Burns	Flush with cold water until the burning sensation subsides.
Cuts	If bleeding is severe, apply pressure or a compress directly to the cut and get medical attention. If cut is minor, allow to bleed briefly and wash with soap and water.
Electric Shock	Provide fresh air. Adjust the person's position so that the head is lower than the rest of the body. If breathing stops, use artificial resuscitation.
Eye Injury	Flush eye immediately with running water. Remove contact lenses. Do not allow the eye to be rubbed.
Fainting	See Electric Shock.
Fire	Turn off all gas outlets and disconnect all electric circuits. Use a fire blanket or fire extinguisher to smother the fire. CAUTION: Do not cut off a person's air supply. Never aim a fire extinguisher at a person's face.