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# Resource letter CPE-1: Computers in physics education

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# RESOURCE LETTER

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This is one of a series of Resource Letters on different topics intended to guide college physicists, astronomers, and other scientists to some of the literature and other teaching aids that may help improve course contents in specified fields. No Resource Letter is meant to be exhaustive and complete; in time there may be more than one letter on some of the main subjects of interest. Comments on these materials as well as suggestions for future topics will be welcomed. Please send such communications to Professor Roger H. Stuewer, Editor, AAPT Resource Letters, School of Physics and Astronomy, 116 Church Street SE, University of Minnesota, Minneapolis, MN 55455.

# Resource letter CPE-1: Computers in physics education

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This resource letter provides a source of information for physics teachers who wish to use computers in physics education. The letter "E" after a reference indicates a relatively elementary item useful for people just beginning to develop an interest in using computers; the letter "I" denotes intermediate level references for people who have already mastered the specialized vocabulary of computer uses; and the letter "A" denotes advanced material for people who have experience using computers in physics teaching. This letter code does not refer to the level of the physics concepts discussed in any of the articles. An asterisk (*) indicates those articles to be included in an accompanying Reprint Book.

## I. INTRODUCTION

The use of computers in physics education is being rapidly changed by the availability of personal computers with increasing power at decreasing cost. Currently there are about one million general purpose microcomputers in the schools and colleges of the United States, and this number is increasing exponentially. Moreover, the computing power per unit cost of microcomputers is doubling about every two years so that, by the time they graduate, today's freshmen can buy microcomputers four times more powerful than the one they can buy today for the same price. There is probably no other area of contemporary life where innovation and obsolescence are occurring at such rapid rates.

The expanding sales of microcomputer equipment (hardware) has provided increased marketing opportunities for the packaged programs (software) to make computers do specific tasks. The amount and variety of such software has been increasing at a dramatic rate. The microcomputer industry has fostered the publication of new computer magazines and books at a rate that seems to exceed that of the proliferation of the hardware and software. These numerous publications have tended to make the traditional modes of communication about computers in physics education obsolete. A typical article in a physics journal appears perhaps eighteen months after the work was done, about the doubling time in the microcomputer revolution. New paths of communication about microcomputers and their uses in physics education will have to develop to take advantage of opportunities presented by microcomputers. To discover what is currently occurring in the use of computers in physics education, the abstracts of the papers given at the national and sectional meetings of the American Association of Physics Teachers, published in *The AAPT Announcer* four times a year, should be consulted. (The Computers in Physics Education Committee of the AAPT compiled a list of these abstracts from 1980 to 1985. This 42-page document is available from the AAPT Executive Office.)

## II. SERVICE SOFTWARE

The professional productivity of physicists can be greatly increased by the use of the general-purpose, service software that is available for the popular microcomputers. While much of this software was originally developed for business uses it is readily adapated to the variety of tasks that physics students and teachers must do. Physics teachers do many tasks repeatedly, for example, write letters; prepare lectures, class notes, and exams; record and determine student grades; and keep an inventory of physics equipment. There is service software commercially available to help with these tasks. For example, consider the following six tasks of physics education that can benefit from service software packages:

(1) Writing. Word processing software (e.g., Word Perfect) can be of great use in the preparation of all written materials. Some of the more expensive software offer mathematical symbols.

(2) Data collection. The common spreadsheet or data base software (e.g., Multiplan or File) can be used for collecting and organizing data, from laboratory results to student exam scores.

(3) Data displays. To translate raw data into meaningful relationships, the electronic spreadsheet and integrated software (e.g., Lotus 1,2,3) can be useful.

(4) Graphs and charts. There is excellent computer graphics software (e.g., MacPaint, Chart) that make it possible to create good drawings and graphs without doing any computer programming.

(5) Solving problems and organizing ideas. Some of the service software can solve algebraic problems (e.g., TK!Solver) and other software is touted as an idea pro-

  

cessor (e.g., ThinkTank).

(6) Communicating with others. The microcomputer with a modem offers access to electronic information networks. The AAPT has established an electronic bulletin board. Call (301) 454-2086.

## III. BACKGROUND READING

*(1) **"Interactive Learning: Millikan Lecture, American Association of Physics Teachers, London, Ontario, June, 1978,"** A. Bork. Am. J. Phys. **47**(1), 5–10 (1979). This paper occurred near the beginning of the personal computer revolution and set an agenda for interactive education. A must read. (E,I,A)

(2) **Learning with Computers**, A. Bork (Digital, Bedford, MA, 1981). Collected papers on computer-assisted leraning. (E,I)

(3) **Personal Computers for Education**, A. Bork (Harper & Row, New York, 1984). A more recent book specifically about personal computers. Excellent for discussions with students and colleagues. (E,I)

*(4) **"Computers in Education: Promise and Reality,"** P. Bonner, Personal Computing **8**(9), 64–77 (1984). Survey of computers in schools. (E)

*(5) **"A Computer on Every Desk,"** D. Osgood, Byte **9**(6), 162–184 (1984). Survey of status of computers in a variety of American universities. (E,I)

*(6) **"Cautions on Computers in Education,"** S. L. Chorover, Byte **9**(6), 223–226 (1984). Raises questions to be addressed in the use of computers in education. (E,I)

(7) **The Micromillenium**, C. Evans (Pocket Books, New York, 1979). Touches on a wide variety of issues from crime to the decline of the professions. Evan's comments about teaching are particularly challenging. (E)

(8) **The Third Wave**, A. Toffler (Morrow, New York, 1980). Suggests that the present age is the beginning of the third tidal wave in history, the first two being the agricultural and industrial revolutions. A related PBS television program was first shown in 1984. (E)

(9) **Computers in Physics Education**, L. Schaaf, H. Jodl, H. Kühnelt, and R. U. Sexl. A very complete list of articles and books about computers and physics education from 1963 to 1983. Available on request from Professor H. Jodl, Unversität Kaiserlautern, Fachbereich Physik, POB 3049, D-6750 Kaiserslautern, BRD. (E,I,A)

*(10) **"Teaching Science With Computers,"** J. Graef, Phys. Teach. **22**(7), 430–436 (1984). A summary of the current uses of computers in science classrooms. (E)

*(11) **"Computer Futures For Education,"** A. Bork, Creative Computing **10**(11), 178–180 (1984). Forty-two provocative statements about computer futures in education are presented. (E)

(12) **Tenth Anniversary Issue, Creative Computing 10**(11) (1984). The whole issue is collective of articles about the history of the personal computer, from the first home kit, Digi-Comp I in 1963, through the first kit minicomputer, Altair 8800 sold by MITS in January 1975, and into the packaged system area, Apple II and Commodore Pet in April 1977. The era of the personal computer is less than ten years old!

## IV. KEEPING UP TO DATE

Once a person has done research in an area of physics it is possible to keep in touch with the main ideas and research results by reading a review article very year or two. In fact, the physics content taught in most physics courses has changed very little since Bohr, Einstein, and Heisenberg. Such a leisurely approach to keeping up to date will probably not suffice for computers in physics education. So much is happening so fast in computer hardware and software. If a group of faculty at the same institution will read different magazines and discuss, on a regular basis, ideas related to microcomputers and education, it will be possible to keep more nearly up to data in this rapidly changing area.

Furthermore, unlike physics, where the latest approved ideas show up only in professional, refereed physics journals, creative computer ideas, useful in physics education, may show up nearly anywhere, e.g., the idea of using a spreadsheet as a map of a scalar field appeared in an article by a homebuilder trying to calculate the brightness of the light shining on the floor of a room from an overhead lightbulb.

### A. General circulation magazines

Most of what is going on in the computer industry is not happening in education first. The general literature gives an idea of what is going on now and likely to be influencing physics education in a few years. Most of these magazines offer product evaluations in every issue. They provide the product announcements and mailing addresses for the computer industry.

**Info-World.** (1060 Marsh Road, Suite C-200, Menlo Park, CA 94025. Phone 800-227-8365.) A weekly magazine of news with both hardware and software reviews.

**Personal Computing.** (10 Mulholland Drive, Hasbrouck Heights, NJ 07604. Phone 800-525-0643.) A general interest monthly magazine of news and feature articles which include product evaluations.

**Byte.** (70 Main Street, Peterboro, NH 03458, Phone 603-924-9281.) This monthly small systems journal features everything from software to circuit diagrams; perhaps one issue a year focuses on computers in education, e.g., June 1984.

**Hardware Specific Journal.** Each of the popular personal computers (Apple II, Commodore 64, IBM-PC, Macintosh, Radio Shack TRS-80, etc.) has spawned periodicals (such as $A^+$, Nibble, and inCider for the Apple computers) which deal specifically with equipment and programs for that computer. These journals can be good sources of information to help answer hardware specific questions.

### B. Computers and education magazines

The increase in the number of magazines on the use of computers in education matches the general growth in the computer industry. New magazines arise and old ones disappear. Check your local education library where you are likely to find *The Computer Instructor*, *The Computer Teacher*, *Computers in the Schools*, etc. All provide a source of information about the companies that are interested in distributing hardware and software for educational institutions. The list that follows is the tip of the computers-in-education iceberg.

**Computers and Education, An International Journal,** Wheaton, Exeter, Great Britain. Features a collection of articles from both sides of the Atlantic.

**The Journal of Computers in Mathematics and Science**

**Teaching** (Association for Computers in Mathematics and Science Teaching, P. O. Box 4455, Austin, TX 78765). A quarterly journal providing information about the use of computers in mathematics and science teaching across all grade levels. It includes new product announcements as well as a bibliography and announcements about meetings and workshops.

**Collegiate Microcomputer** (Rose-Hulman Institute of Technology, Terre Haute, IN 47803). This quarterly magazine provides information about the wide variety of ways computers are used in college teaching.

**T.H.E. Journal** (2922 South Daimler Street, Santa Anna, CA 92705). This journal, published eight times per year, is available free on a limited basis. It is full of short product announcements, hardware and software publications, as well as a few articles relating to the whole spectrum of the use of technology in education.

**Electronic Education** (Suite 220, 1311 Executive Center Drive, Tallahassee, FL 32301). This magazine is published eight times a year and has been available free. It includes articles about people using electronic devices in education as well as announcement about conferences and workshops. This is a magazine that covers all disciplines and spans all of the grade levels of education.

### C. National and regional centers

National and regional computer consortiums and distribution centers are starting up around the country. They offer newsletters, reprints, and software.

**Physics Courseware Laboratory.** (Department of Physics, North Carolina State University University, Raleigh, NC 27695. Phone 919-737-2524.) The laboratory faculty has published software reviews in journals and put together a directory of about 400 commercial and 1600 public domain physics software packages. (E,I)

**CONDUIT.** (P.O. Box 388, University of Iowa, Iowa City, IA 52244.) Originally established with NSF funds to provide a national network for the evaluation and distribution of education software.

**Minnesota Education Computing Consortium (MECC).** (3490 Lexington Avenue North, St. Paul, MN 55112.) MECC was one of the first statewide consortiums established to help schools purchase computer hardware and evaluate and select software. They publish a periodic newsletter about their activities.

**Educational Technology Center.** (University of California-Irvine, CA 92717.) This center generates a variety of educational software and makes available the papers presented by the center faculty.

### D. Users groups

Many cities have a number of users groups, Apple Users, IBM PC users, etc., that meet monthly to discuss various aspects of the use of their hardware and software. They are a source of free, public domain software.

*(13) **"Free Software,"** A. Glossbrenner, Popular Computing **4**(4), 82–84, 180 (1985). (E)

## V. HARDWARE

The hardware manufacturers, such an Intel, Digital, IBM, Hewlett-Packard, Control Data, etc., have some regular periodical that they are willing to send to educators. In addition, the computer magazines keep up a constant flow of information and rumors about the latest advances in computer technology.

Educational institutions and educators are not prepared, financially and psychologically, to purchase equipment that will be out of date in a few years. Much of the apparatus in general physics laboratory classrooms is more than 20 years old. How can they cope will computer hardware which gets better and less expensive every year? Most new personal computer hardware systems are based on one of two microprocessors, either the Intel eight or eighty thousand series of microprocessors (8088 or 80286) that includes the IBM PC or IBM AT and their clones, or the Motorola 68000 series of microprocessors, that includes Macintosh, Amiga, and Atari STs. Byte magazine published a special issue on the Intel system in 1985 and promised a Motorola issue for June, 1986.

(14) **"Inside the IBM PCs,"** Byte **10**(11), 1985. A collection of articles about the details of the Intel based systems. (I,A)

*(15) **"68 000 Wars: Round 1" and "68 000 Wars: Round 2,"** B. Webster, Byte **11**(3), 305–322 (1986) and Byte **11**(5), 343–359 (1986). A first comparison of the Amiga, Atari 520 ST, and the Macintosh. (I,A)

*(16) **"Microcomputers for Physics Teaching: The Shape of Things,"** N. Chonacky and T. C. Ingoldsby, Phys. Teach. **22**(1), 16–20 (1984). A survey of the situation in 1982 (after the IBM PC, before the Macintosh) with hardware acquisition and application development recommendations. (E)

*(17) **"Computer Requirements for Physics Research,"** L. D. Roper, Byte **10**(10), 24–30 (1985). These criteria for physics research enlighten what can be expected soon for physics education. (I)

*(18) **"Using the M68000 for Scientific Research,"** C. Dodge, Byte **11**(3), 24 (1986). (I)

## VI. SOFTWARE

The high volume of sales of personal computers gave birth to the software industry in 1978. Clever programmers developed packaged programs to enable people to get their computers to perform very complex tasks without having to learn a computer language such as Pascal. The primary markets for this service software are business and government, so educators have to be able to develop ways to apply these powerful computer tools to their specific tasks. The time when it seems reasonable to teach every science student a computer language may be rapidly drawing to a close.

*(19) **"All You NEED to Learning About Programming,"** J. E. Fawcette, Personal Computing **8**(12), 183–186 (1984). Understanding how to apply programming concepts to off-the-shelf software packages can be more useful than programming itself. (E,I)

### A. Languages

Although BASIC is the language most commonly found for the personal computers, it is not considered a good language for physics students to learn. Many of the personal computers will also run Pascal, FORTRAN, C, Ada, FORTH, Modula 2, etc. The use of these languages is well documented and almost any large library will contains books with titles such as *FORTRAN for Physics*, *BASIC for Scientists and Engineers*, and *Hands-on Pascal*. The features of the

more recent languages are available through articles in the various computer magazines. The discussion about which language to teach students and why continues undiminished and new languages appear on nearly every horizon.

*(20) **"Languages For Students,"** F. A. Masterson, Byte **9**(6), 233–238 (1984). An evaluation of the suitability of various programming languages for student use. (I,A)

### B. Service software and utilities

In addition to new languages, new authoring languages for teachers and service software for varieties of tasks are always becoming available. Finding the best utility program for any specific teaching task is not easy to do, but many of the general purpose programs are flexible enough to be useful in physics education.

(21) **Visicalc for Science and Engineering,** S. Trost and C. Pomernacki (Sybex, 1983). Gives recipes for using this service software. (E,I)

(22) **"Microcomputer Spreadsheet Programs in the Physics Laboratory,"** R. Feinberg and M. Knittle, Am. J. Phys. **53**(7), 631–634 (1985). A glimpse at some uses for the spreadsheet. (I)

(23) **"Spreadsheet-Gradebook Connection,"** W. C. Straka, J. Coll. Sci. Teach. **15**, 202–205 (1985). Another example of using a spreadsheet in physics education. (E)

## VII. COURSEWARE

The development of a complete physics course using computer assisted instruction is a lengthy and expensive task. Most such attempts were made on the large machines and have been rendered obsolete by the personal computer revolution. The most complete courses in physics to date are the PLATO courses supported by Control Data Corporation (see Refs. 28 and 29 below). Many physics teachers have written a lesson or two on the computer. These individual lessons may be available as a swap, through CONDUIT, or from a commerical software publisher. Regular reviews of courseware lessons are published in *The Physics Teacher* and *Physics Education*.

(24) **Computer Assisted Learning in Physics Education,** edited by A. Bork (Pergamon, New York, 1980). A collection of articles about physics lessons on PLATO, at the Eduational Technology Center (Irvine), and in England at the end of the mainframe era. Many of the lessons are now available on personal computers. (I)

(25) **Physics Software Exchange, A.A.P.T. Announcer.** Each issue contains a list of recent computer programs that physics teachers have written and are wiling to give to others. (E)

(26) **Catalog of Microcomputer-Based Packages,** CONDUIT, the University of Iowa, Oakdale Campus, Iowa City, IA 52242. A nonprofit organization that distributes peer reviewed software packages in the sciences. (E,I,A)

(27) **"Coursewave Review,"** edited by J. S. Risley, *The Physics Teacher*. This regular column in The Physics Teacher evaluates a variety of the available courseware, two of which follow this entry. (E,I)

*(28) **"EDUTECH: Advanced Physics–Schrodinger Equation,"** reviewed by E. Finkel, L. Grable-Wallace, and J. S. Risley, Phys. Teach. **24**(1), 58–60 (1986). Recommends this software for individual and group study. (E)

*(29) **"Control Data Corporation: Physics 1 Series,"** reviewed by L. Grable-Wallace, K. L. Johnston, and J. S. Risley, Phys. Teach. **24**(3), 181–183 (1986). Gives this set of 16 modules an excellent rating. (E)

(30) **Games Nature Plays,** G. Marx, (Dept. of Atomic Physics, Eotovos Univeristy, Budapest, Hungary, 1984). A collection of reprints on the use of the microcomputer in the teaching and learning processes in science. An outstanding resource. (I)

## VIII. LABWARE

In the past decade physics research data has become increasingly controlled and collected by computers. Now computers are being used as multipurpose instruments in the physics teaching laboratories.

*(31) **"Microcomputers in the Teaching Lab,"** R. Tinker, Phys. Teach. **19**(2), 94–105 (1981). A discussion of laboratory uses of microcomputers, using the 6502 microprocessor, but raising issues beyond hardware and software. (E,I)

*(32) **"Using the Apple II as a Laboratory Instrument,"** M. H. De Jong and J. W. Layman, Phys. Teach. **22**(5), 291–296 (1984). Suggests simple circuits and programs for using a computer to make laboratory measurements. (I,A)

(33) **"Apparatus Evaluation–The Versatile Laboratory Aid, VELA,"** M. L. De Jong, Phys. Teach. **22**(5), 334–335 (1984). Evaluation of a commercially available instrument to collect and transfer laboratory data directly to a microcomputer. (E)

(34) **Computer Interfacing, AAPT.** This occasional publication of the AAPT is compiled from the Microcomputer Workshop on Laboratory Interfacing Experiments and contains circuit diagrams and references. (E,I)

## IX. INTERACTIVE VIDEO

The next computer-based technology to have an impact on physics teaching will be the combination of the laser videodisc player and the personal computer. The marriage of these two devices will bring into the physics classroom 54 000 high quality color television pictures with stereo sound, available as a motion sequence or individually at nearly instant random access under computer control. Laser disc players have recently been available for under $200 in stereo/video stores and there is a growing number of discs with subject matter of particular interest to physics students and teachers.

*(35) **"The Puzzle of the Tacoma Narrows Bridge Collapse: An Interactive Videodisc Program for Physics Instruction,"** D. A. Zollman and R. G. Fuller, Creative Computing **8**(10), 100–109 (1982). A description of the first published interactive videodisc for teaching physics. (E)

*(36) **"The Physics Teacher and the Videodisc,"** L. D. Kirkpatrick and D. S. Kirkpatrick. Phys. Teach. **23**(7), 413–418 (1985). A survey of some uses of videodisc to teach physics. It includes a list of the physics and space science videodiscs currently available. (E)

(37) **"Videodiscs and Computers,"** S. Jarvis, Byte **9**(7),

187–203 (1984). Discusses videodisc and computer hardware, formats, and interfacing. (I)

## X. CLOSING REMARKS

Clearly, the impact of the computer on physics education will be profound. No one can begin to see what will be the range of influence the computer will have on the content and structure of physics classrooms in the future. There is one aspect that seems intriguing. Physics has always been fun for physicists. But the intrinsic fun of studying physics has frequently not been apparent to students in physics classes. The students have heard of the difficulty of physics and are often frightened by its substantial reliance on the language of mathematics. It is just possible that the computer can bring fun into the study of physics for everyone.

(37) **"What Makes Computer Games Fun?"** T. W. Malone, Byte **5**(12), 259–277 (1981). A foundation for a theory of intrinsically motivating instruction is laid. (E)

*(38) **"In Praise of Play,"** B. De Koven, Popular Computing **4**(2), 247 (1984). Approaching the computer as a plaything yields the richest rewards. (E)

Feedback is invited: If this resource letter omitted your favorite articles or books, the ones that have helped you bring computers into physics education, please send reprints or references to this resource letter author.