era STALEX with a maximum frequency of 3000 frames per second was employed. In shooting the movie, Czechoslovak Davis Cup player and doubles specialist Pavel Složil played this difficult stroke repeatedly with an effort to achieve a maximum possible spin.

After evaluating all the film material it became clear that the highest rotation obtained was around 3500 rpm. Although this is probably not the final limit of human possibilities these days, it is sufficient to play a fast and effective lob stroke. Therefore, the limiting value of $n = 3500$ rpm also closes the fourth column in Table I. Only for $a = 9$ m, as an illustrative example, the calculation was made for higher spin values of $n = 4500$ rpm and $n = 6000$ rpm. It may be seen that increasing the spin further above 3500 rpm results in accelerating the ball into point C by 0.001 s or by 0.003 s at 6000 rpm. From both viewpoints, i.e., what is practical and possible, it is clear that this insignificant acceleration does not produce any appreciable time gain for the attacking (or defending) player. On the other hand, it can only play a significant role after contacting the playground where it causes the ball to bounce off fast and high with a higher spin requiring more skill returning the ball.

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[1] H. G. Magnus, Poggendorf's Ann. Phys. Chem. **88**, 1 (1853).
[2] J. W. Maccoll, J. R. Aeronaut. Soc. **32**, 777 (1928).
[3] S. F. Hoerner, *Fluid-dynamic Drag*, published by the Author, 1965.
[4] J. M. Davies, J. Appl. Phys. **20**, 821 (1949).
[5] D. Maier, Modellflugzeug, München, 1978.
[6] W. Abe, *Tennis, Forum der Experten* (Verband Deutscher Tennislehrer, Hannover, West Germany, 1983), Vol. 4.
[7] J. L. Synge and B. A. Griffith, *Principles of Mechanics* (Toronto, 1949).
[8] H. Schlichting, *Boundary-Layer Theory* (McGraw-Hill, Karlsruhe, 1968).
[9] K. Květoň, *Set-Up of Empirical Models Using Nonlin and Atlas Programes*, Research Report (Faculty of Mech. Eng., Prague, 1986).

Teaching special relativity through a computer conference

Richard C. Smith
Department of Physics, The University of West Florida, Pensacola, Florida 32514-5751

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A recent seminar in special relativity is described, which was taught exclusively through a computer conference, hosted on a distant mainframe computer, and asynchronously accessed by students and instructor with microcomputer and modem. Nine participants offered more than 400 separate discussion contributions over the 13-week span of the course. Criteria for choosing courses to be offered in this mode are suggested, and problem areas that need attention in the conduct of subsequent courses are pointed out.

I. INTRODUCTION

In a recent article, Halloun and Hestenes[1] addressed the perils we face in the physics classroom if we ignore the fact that our students have preconceived, and often incorrect, notions of how nature behaves. A major part of our task as teachers is to address and correct these erroneous ideas. The "common sense" test described in Ref. 1 shows the extent of the problem and indicates that merely knowing how to calculate the motion of a projectile is not the same as knowing what it does, an important point also recently addressed by Gerhart.[2]

Many, perhaps most, of our physics classes depend almost exclusively on calculation and symbol manipulation, with little opportunity to discuss physics in plain language terms, ones that are rooted in our experience.[3] It seems reasonable to test the idea that successful learning of physics requires the use of word symbols as well as mathematical symbols, and thus we offered our required "Special Topics in Physics" course in a new mode that would require extensive text-based discussion.

The tool for this offering appeared at the same time, namely, the computer conference, in which all contributions to a discussion are made in words or at least entered on a typewriter keyboard. The use of a computer conference allowed us also to test the proposition that college

courses could be offered in a computer conference mode, which allows educators to enable learning in a variety of times and locations, on terms of the students' own choosing.

Accordingly, 8 students and I spent 13 weeks discussing special relativity, contributing over 400 separate comments and notes to 12 topics (e.g., "PROPER TIME," "4VECTOR") of interest within the course. With the exception of the first class meeting, all participation was at computer or terminal keyboards, at convenient times of individual choice.

II. WHAT IS A COMPUTER CONFERENCE?

A computer conference[4] is a dynamic collection of comments, questions, responses, or other text-based material on a common subject of discussion. Specialized conferencing software is used to support this activity, and offers text-editing facilities, easy ways to reference past material, transfer of material between related conferences, and private messaging facilities. Participants are assigned usernames and passwords for each conference of interest, and access the system asynchronously with modems and terminals or personal computers. One participant, often called the moderator, takes responsibility for the conduct of the conference by suggesting new ideas for consideration when the old ones have run their course. A single computer conference shares many characteristics with so-called computerized Bulletin Board Systems (BBSs).

Conferences are either public or private, according to the wishes of the conference moderator. Public conferences are open for discussion from all participants in the system, while private conferences are available only to those selected members specified by the moderator. No user of the system is aware of the existence of any private conferences except those of which he is a member.

An individual user may be a member of several conferences, each with its own topic of discussion. The system maintains individual pointers within each conference, and presents to the user new material in each conference that has been contributed since the user was last present in the conference. Comments and subsequent responses are spaced in time anywhere from a few minutes to several days, depending on the number of conference participants and the frequency of their appearance.

Perhaps the most widely known of mainframe computer conference software is PARTICIPATE, a product of Participation Systems, Inc. Large PARTI systems are maintained on The Source and Unison public on-line computer utilities. The acknowledged progenitor of all conferencing systems is the Electronic Information Exchange System (EIES, pronounced "eyes") of the New Jersey Institute of Technology, itself an outgrowth of EMISARI, created in the early 1970s to manage and implement the wage–price freeze of the Nixon administration. Microcomputer-based conferencing systems exist as well, among them CONEXUS, which runs on an IBM-PC.

III. COMPUTER CONFERENCES IN EDUCATION

The computer conference, with its free discussion and open-ended nature, can be thought of as a systematized seminar, and from there it is only a short step to the idea of a college course.[5,6] There are several advantages that come to mind immediately:

(1) Students in the course (not to mention the instructor) are freed from the place-and-time constraints of typical campus offerings. No one is required to be in Room 230 at 9:30 Monday–Wednesday–Friday, which raises the real possibility of delivering engaging learning experiences to distant learners.

(2) Students are able to consider their own contributions to the discussion very carefully and, if need be, can do their required reading during the actual discussion of the topic.

(3) The system provides practice and opportunity for students to express their thoughts clearly in words, a significant educational by-product of the conference mode.

Several educational institutions are experimenting widely with the computer conference mode of course delivery. The New York Institute of Technology uses PARTI to support the correspondence courses of its degree programs in General Studies, Business Administration, and Behavioral Sciences. New York's New School for Social Research offers courses in a variety of fields through its Connected Education program. The Electronic University[7,8] coordinates and delivers the course offerings of a number of universities across the country. Each course reflects the skills and needs of the individual instructor who serves as conference moderator.

There are a variety of educational applications to which computer conferencing could be put. Entire courses can be delivered in this mode as described below, which gives course access to a wide audience of students. This effectively removes the distinction between off-campus and on-campus sections of a large class, since the course is taught neither "on" nor "off" campus, but via a modem and computer regardless of location. Student advisement for off-campus students becomes more effective. The conference mode is also well suited for applications in which the college or university has strong commitment to support area public schools, since this support can be offered as an ongoing conference.

IV. BASIC ASSUMPTIONS

The decision to offer a physics course in the conference mode was based on several assumptions:

(1) Students can learn from textbooks, given appropriate guidance and assistance, and this guidance can take forms other than lectures.

(2) Students can accept responsibility for their own progress and learning, provided this expectation is made clear to them.

(3) Student ability in a traditional class goes largely untapped, and students can play an important role in explaining concepts to other students.

(4) A computer conference can maintain, or even enhance, the personal involvement of the instructor with the students.

The testing of these assumptions constitutes a test of the conferencing mode itself.

V. COURSE SELECTION

Despite the advantages of course conferencing, it is clear that this mode is not appropropriate for all, or even most, courses. A course is a good candidate for conferencing if it has the following characteristics:

(1) Written material must exist, probably in the form of

textbooks or basic reference material, which can serve as the basic means for transmission of information. A computer conference is a discussion arena, not well suited for transmission of large blocks of text material.

(2) The course must not rely heavily on development of symbol-manipulation skills. Basic mathematics courses would probably be excluded, perhaps symbolic logic courses as well. Those parts of a physics curriculum that are manipulative, such as electronics, should probably be excluded. Physics instructors who approach their subject as purely mathematical will be frustrated by the need, not to say opportunity, for discussing physics in words that can tap the experiences of students. Wheeler[9] has addressed this problem in the formulation of Wheeler's First Moral Principle: "Never make a calculation until you know the answer."

(3) The topic must provide for discussion. A course that involves the mere transmittal of information is not a candidate for computer conferencing. This requirement may not be so exclusionary as it first appears, though physics instructors may find themselves having to develop new kinds of skills.

VI. PHY3936: SPECIAL RELATIVITY

Special relativity was chosen as the topic for the course, with the adoption of the textbook *Spacetime Physics* by Taylor and Wheeler.[10] This text was specified because of the large numbers of "word problems" and the authors' disposition to resort to calculation only after a thorough discussion had paved the way. We used the PARTICIPATE system offered on The Source.

Eleven students registered for the course, though only eight finished, and all were on campus regularly and indeed could have attended a conventional lecture course. The class met formally during the first week, when the rules and procedures of the course were explained and discussed. All agreed that course communication should take place exclusively on PARTI, and that there should be no hall talk on discussion items. One of the departmental Apple IIs was equipped with modem and terminal software, and students were invited to use these at their own convenience. Several students elected to use their own home computers, and two purchased a modem specifically for use with this course.

The course was structured on PARTI as a tree-shaped

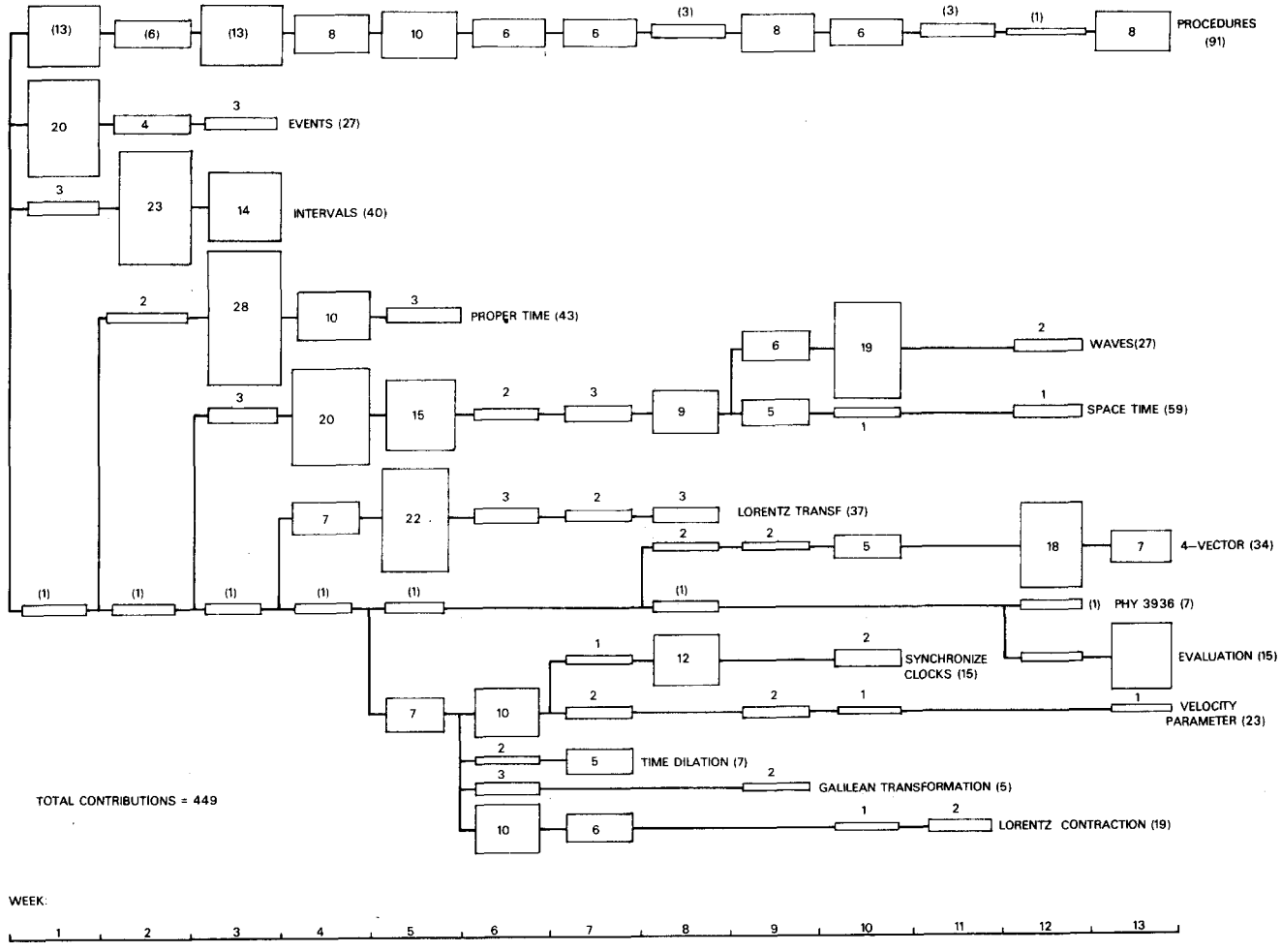

Fig. 1. Time development and relationship of the 15 separate conferences used in the special relativity course. The 13 weeks of the course are depicted horizontally, with the branching conferences shown between the first and last week of their existence. Each conference is named at the right-hand end of the figure. The number of contributions to each conference during a given week is shown numerically and depicted graphically by height of box as well. For example, during week 3, six conferences were in progress, with "PROPER TIME" eliciting the most (28) contributions.

conference, shown in Fig. 1. The root conference, entitled "PHY3936" was the single conference that ran from start to finish of the course, and served as a takeoff point for all the specific topical subconferences. No discussion occurred in "PHY3936" itself. A second special purpose conference was "PROCEDURES," in which ways to use PARTI effectively were discussed. This conference was used for general notices unconnected with special relativity topics. Examples included: (1) how to minimize connect time; (2) advance notices of service interruption; (3) comparison of PARTI with other conference systems. "PROCEDURES" was in use almost every week.

A third conference, "Evaluation," was used to gather comments at the end of the course.

These procedural conferences aside, there developed a total of 12 topical conferences throughout the term:

"EVENTS"
"INTERVALS"
"PROPER TIME"
"SPACETIME"
"LORENTZ TRANSFORMATION"
"GALILEAN TRANSFORMATION"
"VELOCITY PARAMETER"
"TIME DILATION"
"LORENTZ CONTRACTION"
"SYNCHRONIZE CLOCKS"
"4VECTOR"
"WAVES"

Their relationship to each other and the relative activity levels are depicted in Fig. 1.

VII. CONFERENCE ACTIVITY

Several patterns of activity are revealed in Fig. 1. Individual topics had lifetimes of at least several weeks, while "SPACETIME" endured from week 3 through week 12. The usual pattern for a new topic was to have a slow first week, a big jump in interest in its second week, and then decreasing activity until the topic was exhausted. "VELOCITY PARAMETER" was particularly interesting, in that it kept dying off and then being rekindled as a student wanted to return to it. In no case was discussion summarily suspended by the instructor; the hot topic of conversation simply moved elsewhere.

Dependence on technology was well illustrated by the lack of activity in week 11, when the PARTI software was being upgraded and was therefore unavailable for use.

The "WAVES" topic illustrates a basic fact about open-ended discussion: It is not possible to predict where a given conversation is going. The discussion in "SPACETIME" was proceeding nicely, concerned at the time with light cones and signal speed, when one of the students, having read that the refractive index for a diamond is less than unity in the x-ray region, concluded erroneously that x-ray photons traveled faster than c. The student was joined by vociferous supporters with only the instructor to stem the tide. This topic was an unanticipated excursion and required rapid U.S. mail distribution of illustrative dispersion curves, with reference points included, so these could be discussed, leading finally to the difference between phase and group velocity. This, incidentally, is a point that could have been handled quite easily on the chalkboard of a class, but required special attention in the computer conference setting.

VIII. TIME SCALE OF DISCUSSION

The metaphor of a live seminar is very useful, but a seminar differs markedly from a conference course in the time scale of interaction. Live discussions operate with minute-to-minute responses, while the conference course operates on a day-to-day scale. On the other hand, the conference structure supports multiple simultaneous topics, an impossibility in a live seminar setting. Four weeks into the conference course, having introduced one new topic each week (Week 1/"INTERVALS"; Week 2/"PROPER TIME"; Week 3/"SPACETIME"; Week 4/"LORENTZ TRANSFORMATION"; Week 5/ "VELOCITY PARAMETER"; see Fig. 1), we adopted an alternate approach in Week 6, at which time we began simultaneous discussion in "TIME DILATION," "GALILEAN TRANSFORMATION," and "LORENTZ CONTRACTION." The latter approach seemed quite satisfactory, at least for those topics that do not have a prerequisite relationship to each other.

The choice is summarized in choosing whether to spend a week on each of ten topics, say, or to discuss all ten of them for ten weeks. The latter choice, where available, is more suited to the time scale of computer conferencing.

IX. CHALLENGES TO THE INSTRUCTOR

The conference course requires a different set of skills of the instructor, as compared to traditional classroom skills. Among the new skills required are:

(1) Pose questions in a way to invite discussion, not simply answers. This may be a new approach for physics teachers.

Example of poor technique:

Instructor: What's the answer to problem 14?
Student: 44.

Alternate approach, leading to discussion:

Instructor: How would the results of problem 14 be changed if the speed of light was less than the speed of sound?
Student 1: Well, let's see, would that mean that there would be a principle of equivalence for sound?
Student 2: I don't think so. Sound waves still obey the Galilean transformation, don't they?

(2) Deflect requests for individual help. This is a problem only at the beginning of a course, when students, themselves novices at conferencing, tend to ask questions specifically of the instructor: "Dr. Jones, I don't understand paragraph 4 in the text. Can you help?" A seasoned instructor, realizing the impossibility of being an effective tutor to each individual, learns quickly to bring other resources (the other students) to bear: "Well, Frank, maybe you didn't see the footnote in paragraph 3. Mary, can you help out a little? Or how about you, Wes?"

(3) Learn when to keep quiet. An instructor, checking

in with the conference daily, must resist being the first responder to each new student note on the system. The students must always receive the consistent message that they are the ones responsible for a successful conference. A possible rule of thumb: The instructor should never respond earlier than 2 days after a student posts a comment.

(4) Learn new techniques for emphasis. Traditional ways of making points (good eye contact, jabbing of fingers, body language) are useless in a computer conference setting. There are other ways, however, which are quite well suited to this medium: Use capital letters with exclamation points; vary word spacing in a line; scatter words in a pattern on the screen; use arrows for emphasis. And ⟨Gasp!⟩ never forget to include personal human touches in responses ⟨grin⟩.

X. COMPARISON TO CLASSROOM

The inevitable comparisons of the conference mode to the traditional classroom method serve to pose questions that ought to be asked regardless of course delivery method. It is important to avoid the application of double standards. As an example, each participant in the conference course was required to make at least two contributions weekly, which seemed to be an acceptable minimal level of contribution for this 1 semester-hour course. Halfway through the course we all realized that no such requirement was ever placed on students in a conventional classroom setting. The effect was that each student had made at least 26 contributions over the 13-week period, far more than the same students would probably have made sitting passively in a lecture situation.

Student actions and reactions are much the same in the conference mode as in a lecture mode but, in the former, those actions are much more obvious and easy to document. Our class had its share of slow starters, ones who did not begin to participate until the third or fourth week. Those students are in every class, but often the instructor cannot identify them. In the conference mode, it is abundantly clear who is contributing. It is easy to determine which students are listening but not talking. In general, student behavior is much more easily tracked and documented.

A disadvantage of the conference mode is that when students stop participating (the conference equivalent of "not showing up for class") they really disappear. Years of conventional classes have trained students to the discipline of meeting a class at a specified date and time, and if that discipline is not offered, some students will simply drop out, a phenomenon long noted in the high dropout rate of correspondence courses.

XI. GRADING

Grades may be assigned in a conference course in the same way as assigned in a conventional seminar, and these methods vary widely from instructor to instructor. Basis for grading may include subjective judgment of course contribution, an assigned term paper (probably to be mailed in for grading), or, indeed, objective tests that can be administered through the system. The course described herein was offered on a trial basis and was graded on a pass/fail basis, solely on the minimal participation required described above.

XII. TOPICAL SCHEDULE

The tension between the demands of a published topical schedule and the need for open-ended discussion is one that must be faced squarely in a conference course. That the pace of lectures picks up in the final weeks of a term is a familiar occurrence. Such lecturers increase the rate of information transmittal in order to meet the demands of "covering the material." There is little evidence that the rate of information reception and assimilation by the student increases as well. If an instructor is committed to the idea of discussion, then he/she must be prepared to deal with the reality of introducing certain topics that no one wants to discuss. If, in the closing weeks, an instructor introduces topics for discussion at an increased rate, there is no assurance that these will be discussed or understood to any appreciable depth. This realization serves as well to highlight the questionable practice of "covering the material" in a conventional course.

The introduction of "tangential" material into a conference is a related matter. Several students in the class confessed that they found it easy to deflect discussion just by changing the subject, and indeed the course showed several examples of that. Our discussion of signal velocity led to one of dispersion, as described above, thence to chromatic aberration, and, finally, to rainbows and glories, curious topics, one would agree, for a course on special relativity. The discussion was allowed to continue for two reasons: First, there was no satisfactory way to shut down a topic that everyone wanted to discuss, save appealing to instructor authority; and, second, the topic seemed to be a reasonable one for a physics course somewhere, course title notwithstanding.

XIII. COSTS

The costs associated with a conference course are of two kinds: dollar costs and time costs. Real dollar costs are for connect time to the host computer. Public utilities such as The Source and Unison offer hourly charges between $4 and $21, depending on specific published rates, modem speed, and time of day. At an average of $9.00/h, a class of 20 participants, each with a time budget of 1 h/week, would cost $180 weekly just in computer connect time. To be sure, there are ways to reduce the actual connect time, ways that involved off-line editing and uploading of files, but these are fine adjustments to a large expense. These costs are high. Worse yet, the practice of imposing time budgets on the students naturally stifled full discussion and generally proved unsatisfactory.

An alternative to a remote host is to use conferencing software leased and installed on a local mainframe host system. This one-time expense is in the $20–$50K range, depending on the specific system being used, but the costs of operating the system are greatly reduced. The choice also restricts the operation to local usage, one in which long-distance connecting fees are not a factor. This solution takes advantage of mainframe links to remote sites that might already exist.

Still another alternative is to use conferencing software installed on a local microcomputer. This single user, single telephone line system can be mounted quite inexpensively, but such a system will quickly become saturated as the number of users increases.

A more basic question is that of instructor time required

to deliver the course. The 1 semester-hour course described here required an average of about 5 instructor hours per week, the time being greater at the beginning and tapering off to the end. This figure would presumably be reduced as students and instructor both became more accustomed to the new mode.

XIV. THE NEED FOR GRAPHICS

All participants in the course felt hampered by the missing chalkboard. The use of prepared illustrations for discussion addressed this problem to a small degree, but a general solution to this problem must be found before the conference mode can be widely adapted to physics courses. The use of computer graphics to support a text-based discussion is an obvious response, but conventional graphics in this application suffer from two major drawbacks: (1) The information in a graphics screen requires several minutes for transmission over a telephone line, depending on the complexity and size of the picture; and (2) graphics information is critically dependent on terminal hardware. Instructions to paint a graphics image on an Apple screen, say, mean nothing to an IBM machine. It is unreasonable to insist that all conference participants, perhaps scattered over wide distances, have identical computers.

A promising approach to this problem is that offered by the North American Presentation Level Protocol Syntax (NAPLPS),[11] a software standard for transmitting drawing instructions rather than the graphic itself. NAPLPS includes such primitives as circle, arc, and fill, and additionally can change entire screen attributes (colors, text fonts, etc.) with the transmission of a single byte. Instructions for recreating a quite complicated graphic can be transmitted via modem in only a few seconds.

Each conference participant seeking to use NAPLPS graphics must have appropriate encoding and decoding software, but at least the compatibility issue of point 2 above is converted from a hardware to a software problem.

XV. CONCLUSIONS

Computer conferencing offers the promise of delivering physics courses at a distance, and taps and develops verbal skill within students that is largely undeveloped in traditional lecture courses. The two principal drawbacks to using this mode for physics courses are (1) the lack of suitable telecommunications graphics, and (2) the severe drain on instructor time to conduct the conference. We continue work at The University of West Florida in seeking solutions to these problems.

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[1] I. A. Halloun and D. Hestenes, Am. J. Phys. **53**, 1056 (1985).
[2] J. B. Gerhart, Am. J. Phys. **54**, 493 (1986).
[3] R. T. Morrison, "The Lecture System in Teaching Science," in *Proceedings of the Chicago Conference on Liberal Education. Number 1: Undergraduate Education in Chemistry and Physics*, edited by Marian R. Rice (The Chicago Center for Curriculum Thought, The Unversity of Chicago, Chicago, 1985).
[4] B. N. Meeks, Byte **10**, 169 (1985).
[5] *Proceedings of the Exxon/UNC Conference on Computer-Mediated Conferencing Systems and Their Potential Impact on Education, 19–21 August 1984*, edited by J. J. Manock. Available from John J. Manock, University of North Carolina at Wilmington, Wilmington, NC 28403.
[6] J. J. Manock, T.H.E. Journal **13**, 8, 77 (1986).
[7] D. Osgood, Byte **11**, 171 (1986).
[8] A. Glossbrenner, PC Magazine **3**, 21, 297 (1984).
[9] E. F. Taylor and J. A. Wheeler, *Spacetime Physics* (Freeman, San Francisco, 1966), p. 60.
[10] See Ref. 9.
[11] J. Fleming and W. Frezza, Byte **8**, 203 (1983).

Lambda versus first-order transitions

M. Bailyn
Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60201

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If the lambda transition of, say, helium is regarded as taking place over a temperature region, then an integrated latent heat and latent volume that satisfy a Clausius–Clapeyron equation can be defined. The situation is analogous to what happens in ordinary first-order transitions, which suggests a generalization of the Ehrenfest classification scheme for transitions.

I. INTRODUCTION

In the lambda transition of, say, liquid helium, entropy and volume are continuous at the transition temperature T_λ, but the heat capacity C_P and expansivity β_P show peaks there. Integration over the peaks at constant pressure P allows the definition of latent heats and volumes spread over a few degrees of temperature. The ratio of these is just the slope of the transition curve at P, i.e., the Clausius–Clapeyron equation holds in this integrated sense. These results imply that the Ehrenfest classification scheme for transitions can be generalized.