letters

Computer teaching

I speak about machine teaching—the computer teaching—so highly endorsed by Alfred Bork and others (September, page 24): Nowhere ever does the student see or feel or hear *any* of the old-fashioned demonstrations! Can you imagine the student *never seeing* a sphere beating a disk beating a hoop down a hill! Or *never seeing* a spring obey Hooke—or the monkey and hunter—or the double cone that runs uphill—or a man on a rotating stool with a bicycle wheel—or the stick on two fingers—or the projection of UCM—or Archimedes' bucket and cylinder—or a ball on a stream of air—and I can name 1000 more in a jiffy! This machine business is a curse upon us—anathema! It robs the Beauty of Physics—it cheats the student—it is a sickness! It destroys the humanism the subject possesses.

Deliver us from this affliction—this plague—this evil monster—which so abuses the Spirit of Physics.

JULIUS SUMNER MILLER
10.81 *Torrance, California*

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In his excellent article Alfred Bork displays the results of a computer integration of the equations of motion for a planet under gravitational attraction, and he states: "Looking at the figure, we see that the "orbits" in velocity space are circles, something not known to a great many physicists." This is undoubtedly true and we ask "Why?" a question never answered by a computer! The "something not known" is the Runge–Lenz constant of the motion[1]

$$\mathbf{C} \equiv \mathbf{v}\times\mathbf{A} - g\mathbf{r}/r$$

where $\mathbf{A} = \mathbf{r}\times\mathbf{v}$ is constant by Kepler's Law of Areas and $(-g/r^2)$ is the inverse-square law of acceleration. The mass of the planet is irrelevant for gravitational forces.

Place the z-axis along $\mathbf{A}$ and the x-axis along $\mathbf{C}$, transfer $\mathbf{v}\times\mathbf{A}$ to the left-hand side, and square both sides, then

$$(Av_y - C)^2 + A^2v_x^2 = g^2$$

This is Bork's computer-generated circle in velocity space, with (g/A) as radius and (C/A) as displacement, both constants of the motion. (Of course, C is readily expressed in terms of the other constants of the motion, that is, angular momentum and total energy.[2]) We leave to the reader the fun of studying the transition to parabolic and hyperbolic orbits in $(1/r)$ fields; in velocity space they are still circles!

A similarly interesting circle is traced out by the velocity vector in real space. Vector-multiplying the Runge-Lenz vector by $\mathbf{A}$ we can solve for

$$\mathbf{v} = \frac{\mathbf{A}\times\mathbf{C}}{A^2} + \frac{g}{A}\frac{\mathbf{A}\times\mathbf{r}}{Ar}$$

and note that $(\mathbf{A}\times\mathbf{r})/Ar$ is a rotating unit vector perpendicular to $\mathbf{r}$. This also shows the synchronism of the rotations in the two spaces and why the symmetry axes, $\mathbf{C}$ and $\mathbf{A}\times\mathbf{C}$, are at right angles. The new edition of "Classical Mechanics" by H. Goldstein (Addison Wesley, 1980, footnote page 103) shows that the constant of the motion vector, $\mathbf{C}$, was first exhibited by Laplace (1799) and others much before Runge and Lenz. (Perhaps it should be called the Laplace vector.) In addition, our description of the circular orbit in velocity space is just the solution to exercise 24 on page 125, also in the new edition of Goldstein's book.

These results are unfamiliar because planetary motions are studied by painful integration, or playful looking at a computer display, and never reviewed unless quantum mechanics is studied seriously.[3] There is a certain beauty in the family of circles on a computer display, but there is elegance and conviction in a simple analysis. Both methods have their place but teach different things. They add but do not substitute.

References

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2. L. D. Landau, E. M. Lifshitz, *Mechanics*, 3rd ed., Pergamon, Oxford (1976), pp. 35–39.
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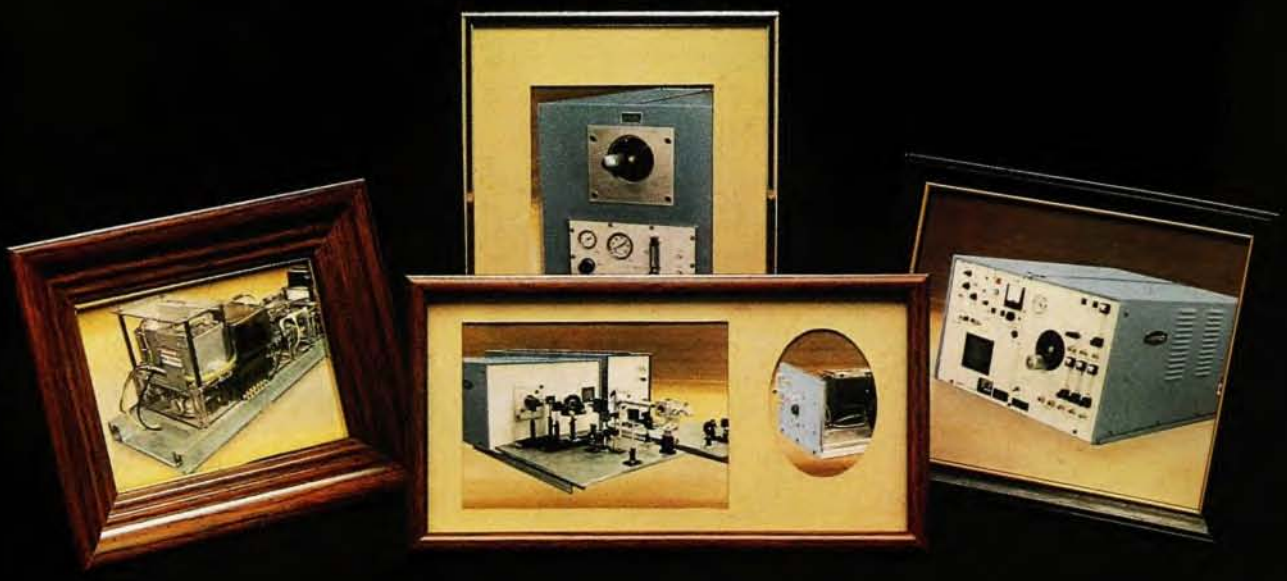

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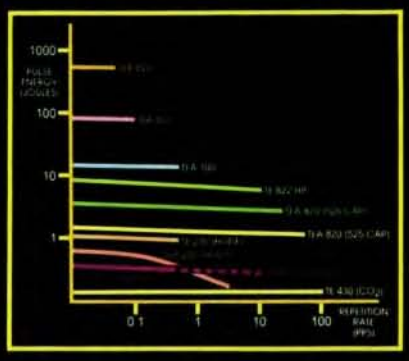

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THE AUTHOR COMMENTS: In reply to Julius Sumner Miller, I should first make it clear that there is absolutely nothing in my paper or in the use of computers in education more generally which precludes the possibility of the usual live "old fashioned *demonstrations*." I don't know why Miller has the view that the computer precludes demonstrations. In fact, there is no reason why one can't do just as many as one would ordinarily do.

I would certainly object that it "robs the beauty of physics—it cheats the students—it is a sickness." I think, in fact, that it has a variety of interesting and important applications and that it can make physics more understandable, more humane, to the student.

With regard to demonstrations, the computer can provide experiences for students, for building up student intuition, which are simply not available in the ordinary world. Thus, it can aid the process of intuitive understanding in the same way that ordinary demonstrations do.

Perhaps it will be difficult to convince Miller of the advantages of the computer in education. But for those who are still questioning, in one direction or another, I suggest that the best way to continue would be to go to a center that has sizable amounts of computer-based learning material, and to spend hours running that material. This experiences is usually a rewarding one for physics faculty.

In reply to William Allis *et al.*, I am familiar with the Lenz vector. In fact, we use it in our beginning course, because it is one of the few examples of a conserved quantity that can be assigned in a problem!

But I don't think that the Lenz vector is the simplest way of seeing that the motion in velocity space is a circle. There are some much easier ways of doing that. The authors might want to consult Andrea di Sessa on their own campus for more information about this.

ALFRED BORK
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Reader frightened

One would not expect to be frightened by reading PHYSICS TODAY, but January contains such an alarming statement that it can in fact be frightening. Glenn Stumpff claims (page 93) that he does "not consider a nuclear war the worst thing that could possibly occur; having to live like Andrei Sakharov is worse." If that opinion were held widely, there could be little confidence in a nuclear counterbalance continuing to preclude world catastrophe. One can only hope that Stumpff's attitude represents merely the extreme fringe, and that neither side of the present counterbalance believes it to be otherwise.

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Nonphysicist as entrepreneur

The article "The physicist as entrepreneur" appearing in January (page 34) was informative, enjoyable and generally accurate.

One example you chose, however, (Coherent, Inc.) does not fit the thrust of your title theme. The founding organizational, financial, product and marketing concepts and strategies were formulated and executed by the purely marketing-oriented founder/president. Those who know him will verify that he does not fit the physicist/entrepreneur model.

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Teach physics—or student?

I have been teaching high-school physics for sixteen years, possess a Bachelor of Science in physics and have done some graduate work in physics education under two NSF grants. Although I have been a member of AAPT for years and read *The Physics Teacher* and PHYSICS TODAY avidly, it has only been within the last year that I have ventured to get involved with the local and national AAPT organization—this through research I am presently doing on the effects grades and testing have on genuine learning.

I have sensed a great deal of concern about the future of physics on the high-school level, the concern that college professors have that they are not receiving the quantity and quality of physics students that they would like and the admissions office's worry that students are staying away from physics courses out of fear of lowering their GPA. Out of this is the anxiety if physics will live or die and if our country can withstand such a collapse of so basic a science.

I suggest that a major factor in this phenomena is that for too long we have been trying to teach physics to students rather than teaching students about physics. If you have difficulty noting the distinction in the prior sentence, that is the difficulty. Each of us must decide if we are primarily teachers or if we are primarily physicists. Although the two are obviously not mutually exclusive, each of us does have a prefer-