LETTERS TO THE EDITOR

Letters express personal opinions and may critically examine any aspect of physics or physics instruction. They need not conform to our regular editorial policy and ordinarily are not reviewed. From the large number submitted, published letters are selected for their expected interest for our readers. They must be brief and are subject to editing, with the author's approval of significant changes. Comments on regular articles and notes are reviewed according to a special procedure and appear in the Notes and Discussions section (see the "Statement of Editorial Policy" in the January issue). Running controversies among letter writers will not be published.

THE TWISTS AND TURNS OF THE TERRELL EFFECT

Given the excellent, stimulating treatment of "relativistic telemetry" by Asher Peres,[1] with its clear and pedagogically attractive presentation, it may appear trivial to take issue with one of his statements were it not for the fact that the misleading impression it conveys seems to be growing ever more entrenched in the literature. In regard to the Terrell effect[2] concerning the instantaneous visual appearance of a three-dimensional, supposedly transparent, object in uniform transverse relativistic flight past a viewer at rest, he asserts that "if a snapshot is taken of a moving object, the latter does *not* appear contracted, but rather *rotated*." When allowance is made for the flight time of light signals from different parts of an object in rapid uniform motion (in the x direction) to a rest viewer who has depth perception, the image will convey the impression of *shear* (i.e., a skew *twist*) rather than of *rotation* (i.e., a *turn*) about a vertical z axis.

The distinction is blurred by the use of relativistic *angular* transformations that describe aberration rather than the (conformal) *spatial-coordinate* Lorentz transformations, which leave the impact parameter (i.e., the y coordinate) and its associated component flight time for light signals unchanged (viz., $y' = y$ and $t'_{y'} = y'/c = y/c = t_y$). Only the x coordinates and the corresponding component flight times undergo transformation. A snapshot, without perception of depth, would presumably not distinguish between shear deformation and rigid-body rotation in the case of the *spatial* Terrell effect, but would readily make the distinction evident in the case of the *temporal* Terrell effect, where the readings and rates of ideal clocks mounted in a transparent lattice array are recorded.

Thus, while Peres' statement in the context of a snapshot image is not, strictly, incorrect it *is* misleading, perpetuating as it does Weisskopf's original assertion[3] that "we see an undistorted picture of a moving object but a picture in which the object is seemingly rotated by the [aberration] angle $\theta' - \theta$. A spherical object still appears as a sphere" when sufficiently remote to subtend an infinitesimal solid angle at the viewer's location. Helliwell[4] picks up the same notion in regard to the appearance of a cubical block, stating that a detailed consideration of the Terrell effect would reveal that the block "will not appear to be distorted, but rather it will look like an ordinary cubical block which has been rotated." Although he employs the word "twist" in his subsequent discussion, it is used in the sense of "turn" (rotation) rather than "shear" (skew). Two later treatments[5,6] do clarify the situation: the illustrations by Scott and van Driel[5] showing differential "twists" in the lines of longitude on a sphere and the more recent discussion by Mathews and Lakshmanan[6] of the appearance of a train of carriages moving on a straight—and stationary—track past a rest observer render the skew effect evident.

The temporal Terrell effect has received rather less attention than its spatial counterpart (a full list of references would go beyond the scope of this communication, but can be supplied on request). While, for a remote viewer receiving parallel signals, the latter seemingly manifests "invisibility of the Lorentz contraction"[2] the former might be deemed to occasion "imperceptibility of time dilation,"[7,8] for which the *shear*, rather than rotation, is vital. For a nearby viewer, the effects become even more interesting. Moreover, if the object undergoes *sustained uniform acceleration or deceleration* while moving relativistically, the effects are even more striking: The apparent deformation in the spatial Terrell effect is perceived as a curved (bowed, warped) shear[9] and clock readings and rates in the temporal Terrell effect take on a fascinating life of their own,[9–14] depending on location and acceleration. Quite some time ago, I submitted an article[15] on this latter topic to the *American Journal of Physics*, discussing in this context "how time flies." It turned out to be too lengthy for publication and, in the spirit of the title, "time's wingèd chariot" has not yet afforded me an opportunity to resubmit it in a more compact format. Meanwhile, the topic has been elucidated in detail by Caviness[14] and is currently being prepared for publication.[16]

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[15]E. Sheldon, A. C. F. Cheng, R. B. Creel, and W. H. Heintz, submitted to Am. J. Phys. (1982).
[16]E. Sheldon and K. E. Caviness (in preparation).

SIMPLE DEMONSTRATION OF COUPLED OSCILLATIONS

In this letter I want to draw attention to a beautiful and thought-provoking demonstration of the behavior of two identical oscillators that are weakly coupled. For many years I taught both mechanics and electromagnetism without being aware of this particular demonstration. I do not know if it is familiar to others since I have not seen it described anywhere.

Take two identical magnetic compasses, of the kind sold by Edmund Scientific Company, a science museum, or a toy store. Set one of them on a table. Allow its needle to come to rest. Now bring the second compass close to the first, shake it so that its needle is set oscillating, and place it on the table close to one end of the needle of the first compass. Watch carefully. The oscillation of the second needle will die away as the first one oscillates with increasing amplitude; then the first one comes nearly to rest again while the second one oscillates. This interchange of oscillation energy will repeat several times before it is damped out by friction.

If you shake both compasses it is possible to observe the two independent normal modes of oscillation whose superposition produces the above behavior. Here, the needles swing with equal amplitudes either in phase with each other or with opposite phase.

Finally, other superpositions of the two normal modes, giving rise to more complex behavior, can be observed.

It is well known that the young Einstein was fascinated by a magnetic compass. Perhaps he also played with two of them. I like to imagine the delight with which he may have watched their coupled oscillations.

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MODERNIZING INTRODUCTORY PHYSICS COURSES

There has been increasing attention to the need to introduce modern physics topics—relativity and quantum mechanics—into introductory physics courses. The 1986 conference at Fermilab gave focus to this proposition.[1] More recently, editorials in this Journal have pointed out that the typical introductory course concentrates on three classical theories—mechanics, thermodynamics, and electromagnetism—at the expense of modern physics.[2]

The debate has brought to my mind a textbook that has been on my shelf for many years.[3] Chalmers W. Sherwin wrote *Basic Concepts of Physics* as an intermediate-level textbook to give students "a unified treatment of this basic discipline"[4] prior to their assimilation of the five or six upper-division courses we traditionally require of physics majors. He gave approximately equal weight to *five* great theories: classical mechanics, relativity, electricity, quantum mechanics, and statistical mechanics. His orientation has a decidedly contemporary flavor.

This is not to suggest that Sherwin's book be used as a prototype in revising our approach to introductory physics. The passage of time, alone, suggests certain cautions. Also, the preface Sherwin wrote should be considered carefully. For example, his 1961 supposition that "the upgrading of secondary school physics that is now under way will inevitably relieve the introductory college courses from carrying such a heavy load of elementary and background information"[4] seems to be invalid in 1987. Nevertheless, the continuous thread that Sherwin used in developing the five essential theories has merit today.

Having said all this I must simultaneously raise a red flag. The great majority of college and university physics is taught in settings that are justified by other than the intrinsic merit of physics. Introductory physics courses are, by and large, service courses for other professions. The pragmatic needs of fields such as engineering, medicine, computer science, architecture, nursing, and other health professions will influence greatly how curriculum committees and accrediting agencies will view restructuring of the introductory courses. Physicists are, of course, imaginative in dealing with complexities such as this. Prudence should be manifest in everything we do as we approach this issue. Perhaps the ancient Greeks said it best. "Nothing to excess."

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1 October 1987

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[4]Quotation from the preface to Reference 3.

COMMENTS ON "COMPTON SHIFT IN ENERGY AND WAVELENGTH—A LABORATORY EXPERIMENT" [Am. J. Phys. 55, 175 (1987)]

In a recent article by Badiger and Thontadarya[1] in this Journal attention was drawn to the fact that the Compton shift in energy depends strongly on the incident photon energy, but the Compton shift in wavelength is independent of the energy of the incident photon.

Another often neglected fact is that Compton shifts and their energy dependencies as stated above are for the limiting case of a photon incident on an electron that is stationary and free. In general, these conditions do not obtain in experiments on atomic electrons that have momentum and binding energies. The momentum and binding energies cause two changes in the Compton wavelength shift that are energy dependent. The momentum of the electron causes an energy-dependent symmetrical broadening of the Compton line.[2] The other predicted energy-dependent wavelength shift, the Compton defect, is asymmetrical and results from electron binding.[3]

Line broadening is easily observed but the Compton defect is difficult to observe because it is small and is masked by line broadening and scattering from electrons in various energy levels. Numerous measurements have demonstrated the energy-dependent line broadening from electron momentum, but experiments have not