The Physics Teacher

What goes around comes around

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Letters

A Weighty Response

As a long-term astronomy textbook author, I felt that Ken Brecher's weighty analysis [*Phys. Teach.* **31**, 326 (1993)] of introductory astronomy textbooks missed a few vital points.

One, what was the nature of his sample? I compared the weight of the 2nd edition of my book, *Astronomy: The Evolving Universe* (1979) to that of the 6th edition (1991). Both have the same trim size. The second edition weighed in at 51 ounces; the 6th at 54! A better comparison might be page count, which is 528 versus 568—a gain of only 8% in 12 years.

Two, as Brecher aptly noted, astronomy has grown astronomically in this period, especially with observations from space telescopes. I challenge him to compare his "growth graph" of textbooks to that, say, of the *Astrophysical Journal* in the same period.

Finally, Brecher points the finger of blame for the increase at the authors and publishers. Wrong! The people who have failed are the *reviewers* of the books, who almost ALWAYS want *more* material added, and the *adopters* of the books, who don't seem to be bothered by using a 640+ page book in a one-semester course. Authors and publishers usually respond to those demands so that their books will (maybe) sell; they are the essential market forces. I have fought very hard to resist them, but it's a tough battle when your peers act so inconsistently and unprofessionally in such crucial matters—text development and selection.

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It All Adds Up

The article by Herbert T. Wood, "The RC Circuit—A Multipurpose Laboratory Experiment" [*Phys. Teach.* **31**, 372 (1993)] prompted me to write this letter.

One of the experiments sophomores do in our calculus-based physics course involves an RC circuit. As may be done everywhere, they plot V vs t, ln V vs t graphs, and obtain the value of time constant from both graphs. (Note: V is the voltage across the capacitor.) Several years ago I made it a little bit more challenging to students by adding numerical integration of the differential equation

$$\frac{dV}{dt} = -\frac{V}{RC} \text{ (for a discharging case)}$$

with the initial condition $V = V_0$ at $t = 0$.

The only hint given is the Euler's equation, i.e., given the differential equation

$$\frac{dy}{dx} = f(x, y)$$

the solution can be approximated (at its simplest level) as

$$y_{(k+1)} = y_k + \Delta x \left(\frac{dy}{dx}\right)_k = y_k + \Delta x\, f(x_k, y_k)$$

At first half of the class is apprehensive, but in two weeks almost everybody presents me with a Fortran program and a graph that they can compare with the experimental graph. (Fortunately they learn Fortran in the first year.)

In spite of the fact that they are not careful about the value of ΔX and that they don't explore a better solution, I consider this assignment a good example of application of mathematical knowledge to physics.

Takao Tekeuchi, *Department of Physics, SUNY College of Technology, Alfred, NY 14802*

Wrong! And That's Right

In response to recent articles on multiple-choice testing, I would like to describe a variation that we have been using for many years with a great deal of success. It allows giving partial credit without giving up the ease of grading of a multiple-choice test. Our questions have one correct answer and three incorrect. Students may mark one, two, or all three of the *wrong* answers. One point is awarded for each wrong answer identified. If the correct answer is marked, no points are awarded for that question, regardless of what else may be marked. In this way, a student who is certain that a couple of answers are wrong can be credited for his knowledge without having to risk everything on a guess.

If a bit of care is used in writing the incorrect answers so that they vary in plausibility, you can learn a lot about your class with a rather small number of questions. (In a sense, each question of this sort is equivalent to four true-false questions.)

"All of the above," "none of the above," and similar answer choices should not be used, since they tend to be even more confusing to the students with this scheme. I always discuss the guessing strategies with the class before the first test. Hand grading of these tests is only a trifle slower, and some mark-sense grading systems are sophisticated enough to handle it. Student opinion has been very positive; they feel that this method is much "fairer" than the normal style of test.

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What Goes Around Comes Around

In the 30th anniversary issue of *TPT*, was it just coincidence that Cliff Swartz predicted a new article on the centrifugal force for year 2023, when such an article appears in that same issue? Let me add one more prediction: shortly after said article will have appeared, letter(s) to the Editor will appear criticizing it...such as this.

In my opinion the note by Bill Wedemeyer (*TPT*, April 1993, p. 238) will add more confusion than clarity to the seemingly endless problem of circular motion. When we refer to a force as *centripetal* we are referring purely to its direction, namely a direction toward a fixed point in space called the center. But like every force it has also a physical nature, and consequently a physical name simultaneously with the directional name. As an example, suppose we twirl a small mass rapidly in a circle on the end of a string (and ignore gravity as relatively unimportant). The centripetal force *is* the tension in the string, the same force by two names. If our use of language were made clear, there would be absolutely no mystery in this.

The force is perfectly *real* by whichever name it is referred to. So long as one is doing Newtonian mechanics in an inertial reference frame, there are no unreal forces. Every force is due to interaction with some object that is clearly identifiable. To introduce the term "force requirement" is confusing and counter productive. By Newton II, whenever any mass m has acceleration a (in whatever direction), then there is a force requirement of $F = ma$; there is nothing particular about the centripetal force in this regard.

A further point concerns the words "centripetal" and "centrifugal." These words do not occur in our everyday vocabulary. For most people, they first arise in the context of physics in conjunction with the "problem" of circular motion, and these strange words seem to carry an aura of mystery and perhaps trigger a feeling of hopelessness that all this will never be understood. If we would just abolish these words, and replace them with plain English, namely CENTRAL FORCE (positive inward, negative outward), then it would be clear that we are simply choosing to name the force by its direction and most of the "problem" would wither away. The *central force* is not necessarily identical to a single physical force, but may be the resultant of several separate forces. In this case central force is just an alternative name for this particular combination of physical forces. This does not affect the fact that it is real.

With regard to the derivation of the formula for the magnitude of the central acceleration, the author states that he "likes" a derivation based on the whole circle. I don't like that at all. The acceleration (unless constant, not the case here) is an instantaneous quantity and *must* be calculated from short time intervals containing the time point of interest. It is a disservice to physics students to suggest by this example that acceleration can be calculated from finite time intervals. How, for example, would one follow up for one period of the harmonic oscillator? Of course the author gets the right answer, but only because of particular conditions that hold in this situation. A rigorous discussion of what these conditions are would be more confusing to the student than just doing the calculation correctly.

I do like the idea of obtaining the velocity circle in velocity space. From there a correct derivation is quite easy. Consider two radial velocity vectors separated by a short time interval Δt and consequently by a small angle $\Delta\theta$ (much less than a radian). The *change* in velocity Δv during this time is represented by the *chord* joining the tips of the two velocity vectors. Now comes the consequence of using a small angle. If the angle is small, the chord has approximately the length of the arc. We have

$$\Delta v = (\text{chord}) \approx (\text{arc}) = (\text{radius})\,(\text{angle}) = v\,\Delta\theta = v\,\omega\,\Delta t$$

where it is assumed that the angular speed ω has been introduced. Then

$$a \equiv \Delta v/\Delta t = v\,\omega$$

which is hardly longer than the author's derivation. If one takes the full circle rather than a small angle, then the arc no longer approximates the chord; in fact the chord length is zero, as is the *average* acceleration over a full rotation.

One last remark. The difficulty in understanding circular motion also derives from a lack of having thoroughly digested Newton's *First* Law, which is often passed over too hastily in our rush to get on with problem solving.

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Sight Distance at Sea

Z.H. Levine's article, "How to Measure the Radius of the Earth on Your Beach Vacation" [*Phys. Teach.* **31**, 440 (1993)] shows the calculation for the sight distance to the horizon. Many years ago my father, who was a teacher of mathematics and astronomy at Roanoke College, posed this same question as we were walking the beach. Later, as he drew the diagram and derived the equation shown by Levine, he inserted units in the English system as was his custom.

If the radius of the Earth is used in miles and the height above the water is converted from *feet* to miles, the resulting value of sight distance is produced in miles. The result is then very easy to remember. Sight distance, in miles, is the square root of $1\frac{1}{2}$ times the height in feet. For example, at 6 feet above the water, sight distance is $9^{1/2}$ or 3 miles. [1]

An interesting variation on this is to ask at what distance, theoretically, can a person 6 feet tall, stranded in a rowboat, see the mast of a rescue vessel if the mast is 54 feet above the water? The result is obtained by adding the sight distances of the two persons, $(1.5 \times 54)^{1/2} + (1.5 \times 6)^{1/2}$, which is 9 + 3 or 12 miles. Clearly this assumes a calm sea with no refraction as the line of sight passes tangent to the water at a point between the two objects.

A related, and mind-boggling, question is: "Given a string circling a sphere of the same radius as the Earth, how much additional string is needed to raise the given string so it is 1 m above the surface of the sphere at all points?" The answer is a neat application of the calculus. If $C = 2\pi R$, then differentiating, $dC = 2\pi\, dR$. For dR of 1 m, then the added string is 6.28 m! Many students will never believe this one.

Reference

1. D.R. Carpenter, Jr., and R.B. Minnix, *The Dick and Rae Physics Demo Notebook* (Dick and Rae, Lexington, VA, 1993), p. S-360.

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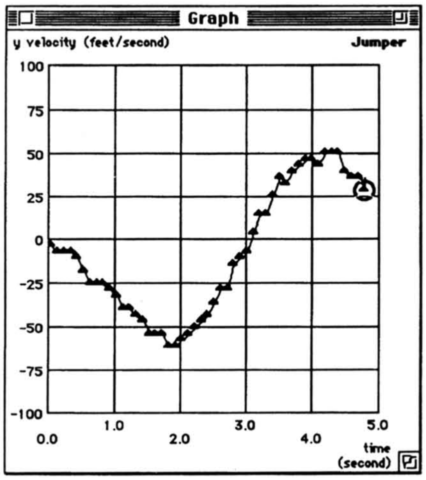
Theory and Experiment

I thought readers would be interested in seeing an experimental verification of some theory presented in the November issue of *TPT*.[1] Paul Menz's fascinating article on bungee jumping reminded me of a video sequence of bungee jumping found on a new videodisc.[2] I was particularly interested in Menz's suggestion that free fall occurred for approximately the first two seconds of a jump, followed by an acceleration somewhere between 2 and 3 g's. Recognizing this as an opportunity to test a piece of software I am writing[3] to play movies synchronized to motion graphs, I quickly captured the motion sequence and produced the following graph. As predicted, the slope for the first two seconds turned out to be -32 ± 2 ft/s^2. The next few seconds find the jumper experiencing an acceleration of about 63 ± 4 ft/s^2. Isn't physics great? Seriously, I think there is real value in having students work on problems that interest them. I commend Mr. Menz for helping AAPT members accomplish that in their classrooms with his excellent paper. I would be willing to bet that there will be at least as many students reading that article as there are teachers!



References

1. P.G. Menz, *Phys. Teach.* **31**, 483 (1993).
2. *Physics at Work*, Videodiscovery, 800-548-3472.
3. *VideoGraph*, development supported by NSF grant MDR-9154127. Image capture was accomplished using *VideoGrab*, a companion package for operating videodisc players and Visca-capable VCRs.

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Correction: Equation (3) in "The Breaking Broomstick Demonstration" (*TPT*, April 1993, p. 230) should read

$$v_e = -2v_{CM} + 6\tau\Delta t/ML$$