More Physics that Textbook Writers Usually Get Wrong

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I discovered a week and a half ago that I have 10 minutes, rather than 15, so this presentation will be brief. However, with that in mind:

This paper, and some other items likely to be of interest, are now posted on my website:

www.introphysics.info

To compensate for brevity here, the written version has been extended a little to clarify some parts of the paper.

That site includes

Introductory Physics for Teachers of Physics
An Introduction to Equilibrium Thermodynamics, Revised
A World of Physics (for 9th grade)
some poems (for our grandchildren)

and some papers considered too long to be published in *The Physics Teacher*, including

Why Things Happen
The Galileo Myth

and some others submitted but not yet published, including

The Work-Energy Theorem
a letter on *Conservation Laws*
and *The Bernoulli Conundrum*

Earlier articles, appearing in *The Physics Teacher* in 1992, pointed out that work is defined, by the needs of thermodynamics, as a mode of transfer of energy between a system and its surroundings.

$$W = (\Delta E)_W$$

New versions of alternative definitions, apparently quite unrelated to the thermodynamic definition of work, generally have been based on the second-law integral,

$$W \; ?\!=\!? \; \int(\sum \boldsymbol{f}_i)\cdot d\boldsymbol{x}_{cm} = SLI$$

This second-law integral fits Newtonian mechanics, but in general has little or nothing to do with energy or with work.

The new twist is like noting that a bat looks somethings like a bird, and insisting that it therefore should be called a “bird-bat” to be sure that everyone will associate the bird resemblance with the bat.

The earlier papers showed that “heat” has too many “technical” meanings to be useful except as a rough association. Problems with undefined "heat" continue, as do the tendency to confuse tension with a force vector.

Finally, difficulties still appear with the factitious forces, especially centrifugal force, which many authors appear to be afraid of and others simply interpret as something else entirely. I have even seen centrifugal force described as the reaction force to a centripetal force, although they are typically along different directions and have different magnitudes.

Moving to new topics:

Problems continue in textbooks:

<u>First</u>:

Consider the tablecloth pull. One textbook close at hand when I was writing this says, "Before the magician pulls on the cloth, the dishes are at rest. So when the tablecloth is whisked away, the inertia of the dishes keeps them at rest."

That, you recognize, is why Wiley Coyote must hang motionless for a while until his inertia decides to turn him over to gravity.

The problem is more easily analyzed for a mass hanging from a thread, pulled downward by a thread below. If the mass *does not* move, the tension in the thread above is the sum of the weight and the pull, whereas the tension in the thread below is only the pull. So the thread would always break above. If the mass *is* accelerated, the tension in the thread above is equal to the weight plus the pull *minus ma*, the mass times its acceleration. If the acceleration is large enough, this sum may be less than the pull, so the thread breaks below.

It's a simple enough problem we have all looked at, but it won't work if the mass does not accelerate.

The pull, *f*, exerted by the lower cord accelerates the mass. The stress, or tension, produced in the upper cord is then

$$T = f + mg - ma$$

If $a = 0$, $T > mg$ and the upper cord breaks, always. The strain, or extension, of the upper cord depends on the time for which the stress acts. It is because the mass does move that the tension is decreased in the upper cord, allowing the lower cord to break first. Because the lower cord breaks quickly, the mass moves only a very short distance, and therefore the strain on the upper cord is small.

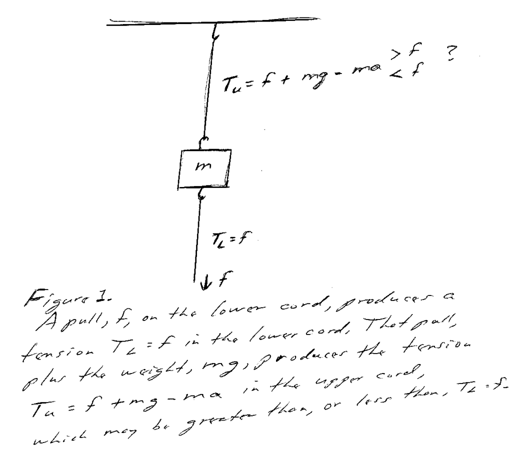

Figure 1. A pull, *f*, on the lower cord, produces a tension, T_L, = *f* in the lower cord. That pull, plus the weight, *mg*, produces the tension $T_U = f + mg - ma$ in the upper cord, which may be greater than, or less than, $T_L = f$.

Similarly, when the tablecloth is pulled, the cloth exerts a force on the dishes equal to the weight of the dishes times the coefficient of friction between dishes and cloth. This produces an acceleration of the dishes toward the edge of the table. If the tablecloth is pulled with sufficient vigor, it slides from under the dishes before the dishes have had time to accelerate to any appreciable speed. The dishes then hit the table surface and, again because of friction, lose their motion.

Second:

Bernoulli's equation is correct, and easily derived from force equals mass times acceleration. It is *not* a sum of energy terms, that remains constant. As has been known for many years, H is constant, and $H = E + PV$, so if PV changes E cannot be constant. And there is no mysterious force that measures the speed of the fluid and adjusts the pressure to fit. Rather, the equation tells us that *if* we introduce a pressure difference, the fluid will be accelerated.

Figure 2. Points A correspond to ambient pressure. Point B is a low pressure region (because of centrifugal force or, equivalently, because the air passing over the wing "misses" this region behind the high point of the wing).

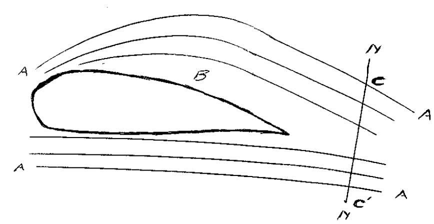

Figure 2. Points A correspond to ambient pressure. Point B is a low pressure region.

But then what causes the pressure difference, for example in air passing over a wing? It is our old friend *centrifugal force*. In the rotating coordinate frame of the air passing over a curved surface, air gets thrown outward by the centrifugal force, leaving low pressure behind which causes the air following in the flow to be accelerated. Or, if you prefer, the air passing over the wing tends to continue in a straight line rather than follow the curved surface, leaving an "air gap" below the flow. Get rid of the curvature and there is no pressure difference or speed change.

As usual, it should be possible to eliminate centrifugal force by choosing a non-rotating reference frame, but I haven't seen anybody do that successfully with Bernoulli flow.

Third:

The conservation laws are among the most important parts of physics, yet our textbooks consistently confuse conservation with what is better called *preservation* — the property of being a constant of the motion, or simply a constant for the system in whatever process is under consideration.

We may agree at the outset that we are restricting the term to the scientific meaning of the conservation laws, ignoring political, ecological, or other distractions. Nevertheless, we find in the recent scientific literature examples of **quantities that have been described as being conserved** that include velocity, energy, mechanical energy, kinetic energy, heat, work, current, volume, and entropy.[1] We might begin to suspect that authors are using the term in different ways.

Returning to our poor example of textbook writing we find:
Bernoulli's equation says the three variables of height, pressure, and speed are related by energy conservation. ... if speed goes up, pressure goes down.

At least the author *doesn't* say $W = \int V\,dP$; that is left for the students to deduce.

I suggest we could help students by introducing another example, substantially easier to grasp. The volume of most systems is easily changed, but if the volume of a system increases, the volume of the surroundings decreases correspondingly. In other words, volume is a conserved variable (despite many statements in the literature that volume is conserved because the volume of the *system* doesn't change).

I'm aware there is at least one person who doesn't recognize that volume is conserved, but I haven't been able to figure out whether the individual doesn't understand the meaning of *volume* or the meaning of *conserved* or, as appears more likely, doesn't understand either.

Fourth:

The toy gyroscope, spinning about its axis and supported at a low point against the pull of gravity, should be called "a physicist's joke"; the joke is on us, because we avoid the simple explanation. We know how to add angular momentum vectors to get the right answer, but sometimes wonder whether our students are happy with that sophisticated approach.

Consider the problem of the pool ball rolling in a straight line, that gets struck on the right side by another ball. We have been saddened and amused by the students who say the original ball will travel at right angles to its original motion, in the direction of the "attacking" ball motion, because *we* know the final motion will be a sum of the initial motion and the impetus.

Now imagine the initial ball is a segment traveling in a circular arc. The perpendicular impetus may be an impact, or may be supplied through an axle, but in either case we should expect the final motion to be very close to the original motion, deflected slightly to the side. That means the new circular motion is close to the original circular motion, rotated slightly about a *vertical* axis. So the rotating wheel is now rotating in a slightly different plane.

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[1] The intent here is not to criticize those who have misunderstood our textbooks, *e.g.*, by confusing constants of the motion with quantities subject to conservation laws.. Therefore specific references are limited to publications that have made a positive contribution to the topic.

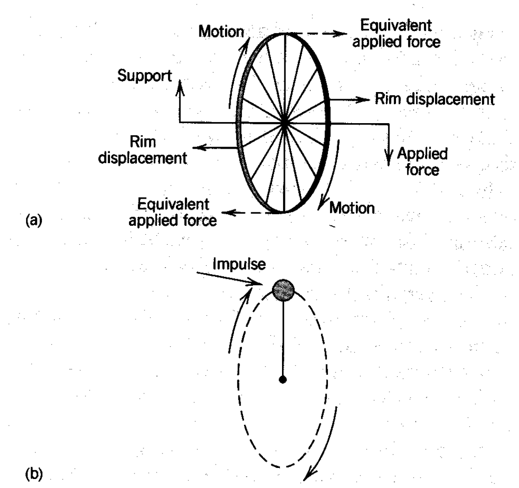

*Figure 3. An impulse, whether applied at the rim or perpendicular to the shaft, alters the motion of a point on the rim, but the resultant motion is **not** in the direction of the impulse.*

This is the motion we usually explain by means of angular momentum vectors, for the gyroscope, or by simple momentum vectors on the pool table.

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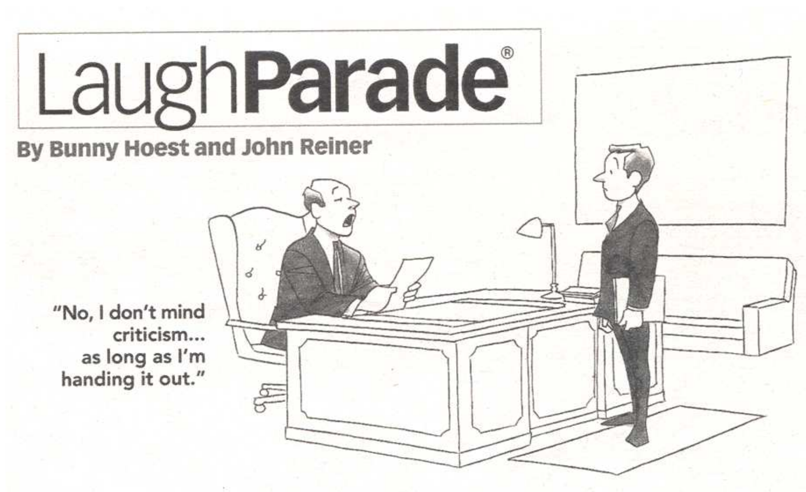
Perhaps I should conclude with a quotation from a cartoon, earlier this summer. One fellow is telling another: "No, I don't mind criticism ... as long as I'm handing it out."



More seriously, I have noticed a great deficit in constructive criticism of physics content, concerning my own writings and apparently also concerning writings of others. We could do much better in that regard.