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ABSTRACT

Examples of errors in statements of physics concepts found in textbooks at all levels are cited and discussed. The author states: "There seems to be a tendency to be deliberately careless in textbooks for the lower levels, apparently in an attempt to be understood more easily." Oversimplifications identified as errors are presented with comments as to their accuracy. (Author/TS)

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Is Physics Easier if Taught Incorrectly?

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ABSTRACT

There seems to be a tendency to be deliberately careless in textbooks for the lower levels, apparently in an attempt to be understood more easily. Examples, like the following taken from a freshman text by a well-known author of excellent advanced texts, will be discussed. Without renewed reference to the internal resistance of the battery the student cannot possibly understand the following description of the behavior of a lamp connected across a battery, described as E, when different resistances are connected in parallel. When the equivalent of a high resistance is connected, "the current from E finds an easier path through the lamp and the lamp glows." When a low resistance is connected in parallel, most of "the current from E [passes through this resistance] and bypasses the lamp." Are students expected to believe that friction disappears when the applied force is larger than the force of static friction, as indicated by the following description of the experiment of flipping a card from under a coin: "If one tries to give [the coin] too great an acceleration, the corresponding force is greater than the friction holding the coin on the card, and the coin suffers no horizontal acceleration at all."

Slide showing two spring balances in tandem, one reading 20 lb, the other 30 lb, to illustrate that two unequal forces acting in opposite directions applied at the same point should be subtracted.[1]

Such examples are presented in junior high school texts and defended in the name of simplifications required for the slow learner. What about the well established law of action equals reaction?

When I point out such erroneous material, I am often asked to explain why such material is being published. I am usually tempted to ascribe it to the incompetence of the author and lack of interest in the low level books by the often impressively listed consultants.

However, when a half year ago a freshman text for nonscience majors by Lindsay[2] had several most peculiar discussions, I began to wonder whether such material is somehow intentionally included. The examples in the abstract are from this book.

Should one generalize Zemansky's jingle[3] to encompass all general physics and not only thermal physics?

Slide: Teaching [thermal physics] general physics
Is easy as a song
You think you make it simpler
When you make it slightly (?) wrong

Slide: Showing the flipping of a card from under a coin, with the explanation that the acceleration of (i.e. the force acting on) the coin is zero. (Ref. 2, p.92)

Is this an attempt to simplify the situation so as to make understanding easier for the student who has little background in physics? It seems to me it might have the opposite effect. The student with good background can perhaps still understand the situation in spite of the misrepresentation, but the less-prepared student must surely give up any attempt of making sense of his physics instruction. He is condemned to memorizing unrelated facts.

Even the simpleminded student will understand that if the force is acting on the coin for a short time only the effect will be minimal. Acceleration times time results in a small sidewise velocity. The sidewise displacement $s = \frac{1}{2} at^2$ will be very small, or the impulse $F \cdot t$ will be small. No matter how one analyzes it, one comes up with a sensible answer. Why complicate the issue by claiming that the acceleration is zero, which would imply that the force is zero. Even this text discusses later on that the force of friction is independent of the speed.

Slide: Showing the experiment of having a high inductance in parallel with an incandescent lamp. When the circuit is connected to the battery E, the incandescent lamp supposedly glows brightly and then becomes dim. When the battery is disconnected, the lamp flashes briefly (ref.2, p.279).

This well-known experiment is described essentially as follows: When the high impedance coil is connected in parallel (during the closing of the switch), "the current from E finds an easier path through the lamp and the lamp glows." When the induced emf is small, "the current from E finally passes (through the low resistance coil) and bypasses the lamp." Does this not appear as if Ohm's Law were violated by having different currents in the lamp, depending on what is connected in parallel; or should one assume that a battery acts like a current source and the current takes the easier path, as so many students like to believe for any circuit. Are the novices expected to remember that several pages earlier the internal resistance of batteries was mentioned. A battery should not be labeled only with its electromotive force if the internal resistance is an essential part of the analysis. The verbal statements without further explanation, or the omission of a letter r on the battery, does not seem to be a meaningful simplification.

If a simplification is desired, one could use battery with little internal resistance and skip the dimming in the steady state or add a resistance in the battery branch to make the effect more noticeable and the analysis less obscure.

There are certainly helpful simplifications in teaching, but one should not omit the essentials. I am not sure whether I admit as helpful the simplified equations which one finds in elementary texts.

Slide:

Often used	Should be
10 kg x 2.2 = 22 lb	10 kg x 2.2 lb/kg = 22 lb
1 ft x 12 = 12 in	1 ft x 12 in/ft = 12 in
10 gm x 5°C = 50 cal	10 gm x 5C° x 1 cal/gmC° = 50 cal

(Ref. 6)

Certainly the second form makes more sense, numerical and unit wise. What if a student divides out the 12 or remembers the commutative law and finds that 12 ft equals 12 inches. Do we really help the slow learners by such simplifications?

I also do not accept as meaningful such a simplification as this statement:

Slide: Nonmetals do not conduct electricity or heat. (Ref. 6)

This is an unnecessary oversimplification which tries to relate conduction of charges and heat, which may be of interest to some solid state physicists but is of no importance to the junior high school student for whom it seems to contradict his daily experience. Most students will realize that one uses storm windows and thermos bottles because heat is conducted by all materials and special heat insulating materials are therefore being used. A distribution between good and poor conductors would be much more meaningful.

Of course, simplification, and isolation of essentials, is one of the important methods of the physicist. Those engaged in advancing the field will rightly claim that most models are wrong. Usually they are subject to improvement and are good for the degree of detail for which they were developed. For example, the Bohr model of the hydrogen atom can be used with good conscience if one is only interested in one-electron systems and the establishment of energy levels and emphasizes that there is more to come. There is no need to embellish this model with features which do not correspond to properties of more detailed wave mechanical models.

Whenever I submit title and abstract for one of these papers, I think 10 minutes should be adequate. When I then assemble the material, I find so many examples to illustrate my point which I would like to share with you that I need twice as much time. If time permits, I will show you a few more examples from texts from which our students learn their pre-college physics. If you have similar material, send it in to the "Would you believe...?" column of The Physics Teacher. Maybe textbook authors and editors will be a little more careful. I have been assured that some of the material presented here today will be corrected in future editions of the Pathway series. But school boards will also pay attention to our complaints. In Denver some books (ref. 1, 4, 5) have been adopted only tentatively with the understanding that the teachers would be provided with an errata list.

Slide: Showing a paper capacitor with paper between foil A and B; but by the time it is rolled up B touches A (Ref. 4, vol. 4, p. 234).

Slide: Showing the magnetic field around a straight wire and claiming that it has poles (ref. 4, vol. 4, p. 111).

Does one not normally associate poles with a surface pole strength or a discontinuity of the magnetic field H?

Slide: Stating that a pulley is an example of wheel and axle (ref. 5, vol. 6, p. 108).

This seems unconventional. Of course, all of these devices can be reduced to a lever, but a wheel and axle is important because of the different lever arms, indicated by using even different terms - wheel and axle. While a pulley is more akin to an equal arm lever. Do grade school children want that much analysis?

Slide: Quoting the reason for heating in compressing a gas: "As gases are compressed, the particles strike the walls of the container more frequently. The more frequent collisions transmit some of the energy of the particles to the walls of the container which makes them hot" (ref. 8 Teacher Guide p.70).

This omits the basic reason for the increase of the internal energy because of the work done by compression and kicking the molecules with the piston and tries to explain the phenomenon in an erroneous way by reference to more rapid heat transfer from the interior to the walls.

Slide: Quoting "When two #6 dry cells are connected in series, we have 3 volt pushing the current through the circuit. But the current produced by the two cells grouped in a series is equal to the current produced by only one cell" (ref. 4, vol. 5, p. 265)

What is gained by contradicting the statement of Ohm's Law that the current is proportional to the applied voltage?

Slide: Showing a 400 lb. block lifted on one edge by a wedge exerting 400 lbs while the block is resting on the other side on the floor. Only 200 lb. of force are needed. (Ref. 1. p.104).

Although it gets more complicated to do it correctly, it does make a lot more sense.

Slide: Indicating the Uranium decay series going from U-238 through Ra 226 to lead Pb-207 (ref. 6, p.136).

Although this seems simple since Pb-207 is listed in the back of the book where atomic weights are only given as integers, it does make it rather abscure how by beta and alpha decays the mass can change from even to odd.

__Slide:__ Showing and discussing interference of waves coming in opposite direction only at the point of first encounter. (Ref. 7, p. 146).

There is no indication that this picture would apply only if the two wave trains had just met. The text seems to imply that this is the appearance of the general interference.

__Slide:__ Quoting that equipotential lines are "lines along which the strength of the field is constant." (Ref. 8, p. 294, etc.)

The source of this misconception or the reason for a simplification of identifying work to get to a point with the force acting at a point is not obvious at all.

__Slide:__ Showing a spectrograph of high resolution without any optical system. (Ref. 9, p.111).

Is such a simplification at the Junior level of college helpful? Or at any level? My colleague teaching modern physics was rather upset when he submitted this example to "Would you believe...?" There is no light collecting system, no collimotor, no focusing system. Only a slit, and remarkable resolving power.

The fact that I have chosen examples from so many books is not because it is difficult to find several examples in a single book but because I wanted to emphasize that a great many books at all levels have items that seem to be hard to justify.

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