EQUATION PUNCTUATION ARGUMENTATION

I usually read David Mermin with pleasure, and particularly enjoyed his column earlier this year encouraging authors to stand up to wrongheaded editors on matters of style. So it was with stunned disbelief that I read his counsel to number, mindlessly, all displayed equations (October 1989, page 9). As a guide to life, this ranks with the recent World Series announcer's ad-lib advice to run outside at the first tremor of an earthquake.

Mermin misses the point: The number beside an equation is not simply an aid to future exegeses but is, more importantly, a form of large-scale punctuation. The numbering of equations is analogous to the paragraphing of sentences, identifying break points in the line of thought. Properly executed, it clarifies the structure of the mathematics: Numbered equations are either starting points or conclusions, important in their own right, or intersections where distinct lines of development come together. A paper in which intermediate equations are numbered simply because they are there is like one of those old BASIC programs that had to have a number for each line of code—sure it's easy to specify where you are, but it's hard to figure out what's going on there.

Mermin's other rules clearly belie his claim that all equations should be numbered. He observes that equations are a form of prose and should be treated as such, and that's exactly right. Would he argue that every sentence should be numbered, like scripture, just in case some reader should wish to refer to it? He observes that a reader shouldn't be sent back through a manuscript in search of equations 2.47, 3.51 and 5.13, and this too is correct. One antidote to such unpleasantness is to number only the noteworthy equations; there are few papers with $47 + 51 + 13$ of these.

We must hope that Mermin will someday rejoin the community of literate mathematical scientists. Until he does, graduate students and other impressionable youth should be discouraged from reading his columns.

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I very much enjoyed N. David Mermin's column "What's Wrong with These Equations?" I would like to consider his Math Is Prose rule, which states that one should end displayed equations with a punctuation mark.

What is the purpose of punctuating anything? It is to provide compact symbolic information that allows the reader to "process" the text with a minimum amount of effort and ambiguity. Too little of such symbolic information *or too much* can lead to extra work and confusion for the reader. The way to prepare the most cogent article possible is not to blindly follow unbendable rules, but rather to use your own common sense in finding the critical point of required symbolic information that maximizes the digestability of the paper. It was Ralph Waldo Emerson who said, "A foolish consistency is the hobgoblin of little minds." Between the extreme poles of the two dictates "Punctuate *all* equations!" and "Punctuate *no* equations!" lies the common-sensible medium "Punctuate displayed equations only if it is necessary to do so to provide symbolic information not already available to the reader." Let's be honest now: 99.$\overline{999}$% of the punctuation required by equations consists of commas and periods. At a primitive level, what information do these symbols convey? They tell the reader to pause a moment before continuing on with the "processing" of the paper. But the fact that a displayed equation is a picture-like object, *almost* always numbered, and indented both horizontally and vertically from the body of the text, is more than sufficient to give the reader a visual cue to pause, rendering the need for a comma or period superfluous.

The weak keystone in Mermin's

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argument is contained in his sentence "We punctuate equations because they are a form of prose (they can, after all, be read aloud as a sequence of words) and are therefore subject to the same rules as any other prose." This reasoning is rather arbitrary. Yes, they *can* be read as a sequence of words, but in fact they never are. Treating the equation as a linear string of symbols occurs only while it is typed, not while it is read. The mental assimilation of a formula is more akin to gazing upon a painting by van Gogh than reading a sonnet by Shakespeare. The formula arrives as a gestalt: a unified symbolic configuration having properties that cannot be derived from its parts. It strikes the mind like a pebble dropped into a pond—sending wavelets of coded information to every nook and cranny of our internal mathematical processors. Semi-isolated formulas are not "droppings on a lawn" as Mermin contends, but rather jewels lying in the sand. Formulas are not read as prose and hence should not be punctuated as such.

Let us not forget that as physicists our primary language is mathematics, and the information that we wish to convey is almost always of a mathematical or numerical form. That we must embed our equations in a scaffolding of prose for the sake of continuity, clarity, and elaboration should not blind us to the fact that by the very nature of our work the equations hold a place of primary importance and the prose is secondary. To subjugate our formulas to the same punctuation rules as ordinary prose is artificial and pedantic and ignores the true ordering of things. I think that many of us feel that to put a trailing, disembodied period after an eight-line equation is just plain silly—and it looks weird too, as it does not really seem to "belong." Does this period really inform the reader to take a break at the end of the expression? Listen: After spending the better part of an hour poring over such an equation, I have long since have forgotten whatever sentence the formula was stuck in, and nobody needs to tell me to take a break. Like a gem in the sand, a formula cannot be integrated seamlessly into its surroundings.

I doubt that I have converted Mermin with my entreaties—the trenches are dug and the war rages on. I hope that I have provided ammunition and a morale boost to the valiant soldiers on my side of the front, and a pat on the back for PHYSICS TODAY and *Foundations of Physics*, two vanguard publications that do not needlessly punctuate displayed equations.

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David Mermin's rules for integrating equations into scientific text make a lot of sense. I was particularly gratified to see the case for numbering all displayed equations argued so persuasively.

However, there are problems, I believe, with Mermin's Math Is Prose rule. Mermin invites the reader to try leaving out the question mark in a question ending with an equation. I tried the converse exercise, writing a sentence *with* a question mark. Take Mermin's equation 1,

$$F = ma." \quad (1)$$

A reader looking at this equation might wonder, What did Newton have in mind when he wrote

$$F = ma."? \quad (2)$$

To another reader, looking at *this* equation, it might seem as though Newton doubted his famous discovery. Or was he just confused by the punctuation marks?

OK, I'll stop being awkward and accept the convention that in reading or referring to numbered equations one must distinguish between symbols that belong to the mathematical expression and punctuation marks, which do not. So I should have applied a math–prose filter before quoting Mermin's equation 1 (despite Mermin's postulate that math is prose). However, even without the fossil punctuation, equation 2 is ambiguous for the casual reader not aware of the particular punctuation convention being used.

But what if Newton really had been a doubter and had written

$$F = ma?? \quad (3)$$

Problems? Not really, just apply the math–prose filtering rule. No, wait, first an auxiliary rule is needed: Neither Newton nor the writer is allowed to use exclamatory double question marks. This rules out the interpretation of an excessively worried Newton or an overemphatic writer. The second question mark must be the writer's and part of the prose, and the first Newton's and part of the mathematically abbreviated question "Is F equal to ma?" The interpretation is unique. But at this point the reader may be wondering whether it might not be easier to explain Newton's law to an undergraduate arts class than the consistent application of the Math Is Prose rule to the

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readers of PHYSICS TODAY.

Perhaps we should agree to avoid encumbering equations with real or virtual punctuation marks other than periods and commas. Logically, the convention of mentally adding a period or comma to a mathematical expression to complete the prose appears neither better nor worse than the convention of mentally deleting mathematically meaningless punctuation added to a set of symbols explicitly identified as mathematics by an equation number. Ultimately, it boils down to a question of taste.

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The Reference Frame article "What's Wrong with These Equations?" by N. David Mermin, reminded me of various battles that I have fought and lost. I too am one of those who is seen as flawed by, in the words of the author, "a preference for form over substance."

In some battles, collaborators have been the adversaries. Many years ago my coauthors ranged from zero through one in number and were either as pedantic as I or responsive to bullying. Now I have drifted into a field where large collaborations are necessary to get the work done and to make the effort look respectable. Papers are stitched together by many farflung colleagues, and the results are hardly evitable. When I object to things like "the chambers were studied using a program . . . ," I get puzzled looks from young punklets who have a perfect right to ignore me because they know so much more physics than I.

The problems addressed in the Reference Frame column have, however, more to do with the evils of editorial policy. From those, too, I have suffered. Books are seldom at issue because generally authors are able to prevail, especially now that few commercial publishers have editors that know enough of either physics or English to put up a serious fight. Journals are mixed in their policies, as Mermin points out, but at least the AIP research journals are quite reasonable. Here, I would like to comment on encyclopedias.

Encyclopaedia Britannica and *Encyclopedia Americana* present equations in various ways; some are poor but most are good. Paradoxically, it is scientific encyclopedias that often disappoint. The *Encyclopedia of Physical Science and Technology* (Academic) and the *Encyclopedia of Materials Science and Engineering* (Pergamon) use equations properly as parts of sentences, but fail to put punctuation after the equations. It can be worse. With hesitation and regret, I must describe the style used in the *McGraw-Hill Encyclopedia of Science and Technology*, a useful and generally excellent work with which I have had an almost satisfactory relationship for years. There the equations are uncoupled from the text, with results such as the following:

> . . .With this replacement, Eq. (18) holds. In other words, whereas the classical ca-
>
> $$(xp_x - p_x x)\psi = i\hbar\psi \qquad (18)$$
>
> nonically conjugate variables x and p_x are numbers, obeying the commutative law in Eq. (19a), the quan-
>
> $$xp_x - p_x x = 0 \qquad (19a)$$
> $$xp_x - p_x x = i\hbar \qquad (19b)$$
>
> tum-mechanical quantities x and p_x are noncommuting operators, obeying Eq. (19b).

Admittedly, I searched a little to find this specimen—it doesn't come from my article because I have learned to write defensively—but it illustrates accurately the editorial policy. That policy is firm. Long ago, I wrote the editor very solemnly that I was worried about severe damage to my literary reputation. The editor assured me even more solemnly that since the style is imposed uniformly, it should not reflect in any way on the contributing authors.

The problem is serious because the young consult encyclopedias. The issue is therefore one of the corruption of our youth.

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MERMIN REPLIES: Would Warren H. White enjoy looking something up in a book that, eschewing the mindless convention that all pages have numbers, reserved them for only the really important ones? I've encountered just that frustration in working my way around books and papers whose authors felt that only a small fraction of the equations were splendid enough to deserve a number. Like page numbers, equation numbers help you to hunt down the one you're looking for. Otherwise why give them consecutive numbers at all—descriptive names would do as well. The more numbers you have, the easier it is to find your way around.

There are many ways to signal that an equation is important without depriving the unimportant equations of the numbers that help you find your way to the important ones. The best way is to write so vividly that it is obvious to the reader that something really noteworthy is about to appear on the page. But even without daz-

zling verbal fanfares for wonderful equations, there are plenty of other devices less disruptive than not numbering the undeserving ones. You can use stars for your prize equations, you can box them, or you can put the equation number in boldface. To be sure, *Physical Review* will fight tooth and nail to prevent you from exercising any of these useful options, but if we yield to that journal's timid notions of good style we will never be able to revive the noble art of scientific writing. We must insist.

Nor does it make sense to maintain that numbering equations conflicts with the Math Is Prose rule. Equation numbers are not part of the prose, as is evident from the fact that the punctuation mark appears directly after the equation, but well before the equation number, which resides at a respectful distance near the margin. Equations are no more undeserving of numbers because they are prose than a page of text is undeserving of a page number.

Jonathan P. Dowling is simply wrong when he asserts that virtually the only punctuation required by equations consists of commas and periods. Equally common, and just as important, is the legitimate absence of any punctuation mark, a degenerate form of punctuation that can reveal much about the relation of the equation to the text that follows, but only if periods and commas have also been provided in the contexts that require them. Why on earth should the reader have to guess or deduce whether what follows the equation is a new sentence, a new clause or an extension of the clause that was in progress when the equation made its appearance? Reading mathematical analysis is hard enough without depriving the reader of the kinds of clues available to the reader of any nonmathematical text.

I sympathize deeply with Rolf G. Winter on the agony and hazards of collaborative writing, particularly when the collaborators are unresponsive to bullying. One good trick is to make sure that the master file stays in your own computer, but networking has undermined even this simple stratagem. Even more discouraging is to submit one of those lovely papers written precisely to your taste without collaborators, only to discover that you have acquired one in the editorial office.

I think a proper use of quotation marks disposes of the particular issues raised by Klaus Hasselmann, but he started me worrying. One punctuation mark—the exclamation point—has an independent mathematical

meaning. Ordinarily this causes no confusion, because if the exclamation point appears as a factorial sign at the end of an equation that does not end a sentence, then the text that follows will begin with a lower-case letter; conversely if the equation culminates a thought so exciting as to require an exclamation point, this will be signaled by the next word's starting with an upper-case letter. Ambiguity might result if that word were a proper noun, but even then it should almost always be clear from the syntax whether or not it heralds the start of a new sentence.

If, however, we allow the punctuation mark"!?"—commonly used to indicate shocked disbelief—then we are in deep trouble, as the following specimen reveals:

Would you believe somebody who maintained that

$$24 = 4!? \qquad (1)$$

Either way you read it, the sentence has definitely ended. Yet the answer can be "Absolutely!" or "Definitely not!" The solution is simple. We must ban "!?" and express our shocked surprise only by "?!"—a small price to pay if it helps revive the noble art of scientific writing. Could anyone possibly disagree?!

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4/90

Publicity's Place in Science

Robert Jones (September 1989, page 142) writes: "Newspapers and press conferences are no way to disseminate scientific results. They are a way of seeking publicity, plain and simple, and need to be discouraged." This coin has two sides and is not, as it might appear on the surface, a simple and straightforward issue. By virtue of the computer revolution and other forces, we are entering a period where small high-technology companies are engaging more and more in basic, fundamental studies of interest to pure as well as applied science. Some of us are paying out of our own pockets to do basic research in our own private facilities, for reasons such as protecting intellectual properties. (I have been doing this, as a matter of public record, for over a quarter of a century.) In recent years non-PhD engineers have won Nobel Prizes, and this trend can only continue.

If I were Jones, I would not be concerned with the construction of homemade hydrogen bombs so much as with the ethical and moral standards of the academic community. Referees should be named and required to identify themselves; otherwise, we may soon be unable to publish a paper without a lawsuit. In view of the number of professors and others who are operating various businesses on the side, there always exists the potential for a conflict of interest.

Our nation needs the contribution of self-funded individuals, as well as small high-tech startups, if it is to survive. With regard to prepublication public relations, shareholders also have certain rights. PR hastens commercialization by attracting money, talent and joint venture partners. (Thomas Edison, incidentally, was the master at getting funding this way.) Publicity can also speed development, by inducing other people doing similar work to "come out in the open." And while public announcements should not circumvent the normal review process, releasing one's findings after a paper has been in a journal's hands for several months can sometimes move that process along.

News conferences and press releases, like most things in life, have their place. Ultimately, therefore, the bottom line is the *truth* and strength of the documentation for the claims being made. All of us, as individuals or organizations, have the right to survive, and publicity in the media is often the only way out.

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9/89

Learning Compelled Is Learning Repelled

I agree with James F. Jackson (January, page 112) that physical scientists could stand to have a better image in the eye of the typical high school student. However, I think Jackson should reconsider his statement " 'Skills' are not as important as knowledge." Forcing scientific knowledge on students tends to turn them off, rendering them antiscientific; only the very few will become scientifically literate or want to pursue scientific careers when taught this way. I question whether it is wise to spend more money on compulsory science education after decades of poor results.

Morris Shamos addresses the issue of achieving scientific literacy in America and offers alternatives in an excellent and thought-provoking article entitled "The Lesson Every Child Need Not Learn" (*The Sciences*, July–August 1988, page 14).

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2/90