THE IMPORTANCE OF MULTIPLE SCATTERING

I was delighted to find the article by Craig Bohren in the June issue of this Journal [Am. J. Phys. **55**, 524 (1987)]. As he so elegantly stated, there are many natural phenomena that are directly attributable to multiple (incoherent) scattering. What he left out, however, are the common commercial applications of multiple scattering. The two-flux formalism described by his Fig. 1 forms the basis of a theory of radiative transfer published by Kubelka and Munk[1] and made practical by Kubelka.[2,3] The color and hiding power of all paints, plastics, inks, foods, drugs, and textiles are formulated on the basis of this model. The Kubelka–Munk solution to Bohren's Eqs. (2) and (3) can be written in terms of measurable quantities such that the measured reflectance R is given by

$$R = 1 + (K/S) - \sqrt{[(K^2/S^2) + 2(K/S)]},$$

where K and S are equivalent to Bohren's kappa and beta and R is the measured reflectance of an optically thick layer of material.

The application of a "two-stream" multiple scattering theory to reflectance spectroscopy has been intimately involved with the development of our society and economy. That the days of buying a car in "any color as long as it is black" are far behind us is due, in large part, to the efforts of physicists and chemists who, like Professor Bohren, took the time to provide their students with a look at the broader picture. Like Bohren, I wonder why this topic is never presented to students of optics.

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[1]P. Kubleka and F. Munk, Z. Tech Phys. **12**, 593 (1931).
[2]P. Kubelka, J. Opt. Soc. Am. **38**, 448 (1948).
[3]P. Kubelka, J. Opt. Soc. Am. **44**, 330 (1954).

MORE ON *g*?

Physics teachers must emphasize that "the acceleration due to gravity" is an unfortunate name for g. Even though it is often called an acceleration, it does not, in general, usually refer to an acceleration as recently suggested.[1] In fact, it is this misunderstanding among students that leads to confusion since mg is often only one of the forces in the problem (e.g., inclined plane). Physics is full of confusing and misleading names (e.g., "spin") and always will be. It is the role of the educator to make the relationship between physical principles and the names of things clear. For a heavenly body of mass M and radius R, the "constant" $g = GM/R^2$ (or the "parameter" $g = GM/r^2$ for $r > R$ if you want to be more general), where G is the gravitational constant. The condition $a = g$ (for acceleration a which appears in Newton's Second Law) is a very special case. I think those aspects of recent letters[1,2] that discuss names of, and units for, g are not very helpful or relevant.[1,2]

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[1]M. Iona, Am. J. Phys. **55**, 104 (1987).
[2]O. Haszpra, Am. J. Phys. **54**, 679 (1986).

COMMENT ON LETTER BY H. ERLICHSON [Am. J. Phys. 55, 104 (1987)]

With respect to a recent letter of Professor Erlichson[1] I would like to make the following remarks:

The Cartesian physics is a space-time doctrine while the Newtonian physics is a space-time-mass one.[2] For example, the Cartesian quantity of motion has the dimension $(L^3)(L/T) = L^4T^{-1}$, whereas the Newtonian quantity of motion has the dimension MLT^{-1}. Consequently, the formulation of the concept of density

$$\left(\frac{\text{Newtonian mass of the body}}{\text{Volume occupied by the body}}\right)$$

is impossible in the context of the Cartesian physics.

Descartes "identified matter with extension and regarded extension as the chief characteristic of matter."[3] The Cartesian identification of matter with extension (volume) does not imply that quantity of matter was used within his physics as an independent element. In fact, quantity of matter does not enter in the Cartesian physics as an independent element.

A consequent formulation of the concept of density requires the idea of a given quantity of matter in a given volume. In order to formulate the concept of density two other basic concepts were historically necessary: Atomicity and Vacuum.[4] In fact, both concepts are not present, due to philosophical impossibility, in the Cartesian physics. Descartes conceived the divisibility "*ad infinitum*" of the parts. A restriction to this divisibility would be a severe limitation of divine omnipotence; for this reason the atomicity constitutes an unacceptable concept for Descartes.[5] On the other hand, the communication between the parts requires, for Descartes, a medium; for this reason vacuum was denied in his physical doctrine.[6]

The Cartesian theory of condensation and rarefaction, referred to by Professor Erlichson, is an intricate intellectual construction based only in the extension and motion (a LT physics).

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[1]H. Erlichson, Am. J. Phys. **55**, 104 (1987).
[2]M. Schönberg, *Pensando a Física* (Brasiliense, São Paulo, Brazil, 1985), pp. 45 and 51.
[3]M. Jammer, *Concepts of Space* (*The History of Theories of Space in Physics* (Harvard U.P., Cambridge, MA, 1970), 2nd ed., Chap. 4, p. 99. See also M. Jammer, *Concept of Mass in Classical and Modern Physics*; Italian translation: *Storia del concetto di massa nella fisica classica e moderna* (Feltrinelli, Milan, Italy, 1980), Chap. VI, pp. 65 and 66.
[4]J. B. Bastos Filho and R. M. Xavier; Notas de Física No. 55/86 CBPF Rio de Janeiro, submitted to "Cad. Hist. Filos. Ciênc."
[5]R. Descartes, Principes de la Philosophie, part II, Sec. 20. Oeuvres et Lettres Bibliothèque de la Pléiade, p. 622.
[6]Reference 5, part II, Secs. 16, 17, 18, and 19, pp. 620–622.

RESPONSE TO "MISSING CITATIONS"

Recently, I read a letter by G. Faucher[1] concerning my note on the angular momentum operators,[2] which did not cite an earlier paper by Gupta