J. Phys. D: Appl. Phys. **22** (1989) 849–850. Printed in the UK

LETTER TO THE EDITOR

On Peoglos' measurement of the force on a portion of a current loop due to the remainder of the loop

J P Wesley

Weiherdammstrasse 24, 7712 Blumberg, FRG

Received 8 March 1989

Abstract. Peoglos reports forces on portions of a current loop due to the remainder of the loop which are in excellent agreement with the direct integration of Ampère's original force law. Peoglos has not, however, confirmed the non-physical absurd Biot–Savart law: it predicts ambiguous, and thus non-testable, results for the force on Ampère's bridge. It predicts merely fortuitously the correct Ampère force on a straight portion, since only lateral forces are measured. The force is not generally given by $2F_x = I^2 \mathrm{d}L/\mathrm{d}x$ and could not, in any case, distinguish between the Ampère and Biot–Savart laws.

Peoglos (1988) is to be congratulated for performing a most difficult experiment to measure the small force on a portion of a current loop due to the remainder of the loop. He has overcome some of the vexing problems that have plagued previous attempts. It was gratifying to see that his results accurately confirm Ampère's (1823) original empirical force law. I (Wesley 1987)† integrated Ampère's force law directly for the force on Ampère's bridge (called a D-type frame by Peoglos) and obtained the result

$$F = 2\times 10^{-7} I^2 \times [C + \ln(b/r) + \sqrt{1+b^2/a^2} - \ln(1+\sqrt{1+b^2/a^2})] \qquad (1)$$

using Peoglos' notation and units, where C is a constant given by

$$C = \tfrac{13}{12} - \tfrac{1}{3}\pi + \tfrac{2}{3}\ln 2 - \tfrac{1}{2}\ln\pi = -0.074131\ldots. \qquad (2)$$

(A wire of cross-sectional area w^2, as assumed in my theory, has been approximated here by πr^2 to match Peoglos' cylindrical wires.) Introducing Peoglos' values $r = 6\times 10^{-2}$ cm and $b = a = 10$ cm, into my result (1) obtained from Ampère's law predicts the force

$$F/I^2 = 11.1494 \times 10^{-7}\ \mathrm{N\,A^{-2}} \qquad (3)$$

which may be compared with

$$F/I^2 = 11.2 \pm 0.5 \times 10^{-7}\ \mathrm{N\,A^{-2}} \qquad (4)$$

found by Peoglos.

For the force on a 6 cm straight portion of wire with each end 2 cm from the sides (called an L frame by Peoglos) the lateral force was found by Peoglos to be $F/I^2 = 3.05 \pm 0.06 \times 10^{-7}$ N A^{-2} in agreement with the force given by Ampère's original law of 3.05133×10^{-7} N A^{-2}.

Peoglos' otherwise excellent paper is marred by introducing the old unphysical and absurd Biot–Savart law. It is 'unphysical' as it violates Newton's third law, as is well known, and it is 'absurd' as it does not always yield a unique prediction nor conserve energy (Wesley 1983). For example, a direct integration of the Biot–Savart law for the force on Ampère's bridge (Wesley 1987) gives two different answers, neither of which agrees with the experimental result found by Peoglos.

Knowing that the incorrect Biot–Savart law yields the correct Ampère result for the force between closed current loops, Peoglos states, '. . . isolated current elements cannot exist.' But, of course, isolated current elements can and *do* exist! Magnetic forces also act on and between isolated moving charges!

Since the self inductance L follows from Weber's generalisation of Ampère's law; it is not too surprising that the force given by $(\partial L/\partial a)I^2/2$ yields a force on Ampère's bridge in agreement with Peoglos' observations. The constant C in equation (1) must, however, be replaced by

$$C' = 1 + \ln 2 - \tfrac{7}{4} = -0.056852\ldots, \qquad (5)$$

indicating a fortuitous agreement rather than any actual agreement. For example, using the formula $\frac{1}{2}(\partial L/\partial a)I^2$ to try to get the force on the straight portion (the L frame) yields $F/I^2 = 6.69 \times 10^{-7}$ N A^{-2}, over double

† Equation (15) has a sign error: $-\frac{2}{3}\ln 2$ needs to be written as $+\frac{2}{3}\ln 2$.

0022-3727/89/060849 + 02 $02.50

that observed by Peoglos.

The fact that the Biot–Savart law when integrated directly gives the correct force on the straight portion (the L frame) is merely fortuitous. In general, the Biot–Savart law will not work when integrated directly over a portion of a current loop. For example, the force on an arc of a circular current loop will not be correctly predicted. Only when the portion under consideration is constrained so that the Ampère repulsion between collinear current elements cannot be registered can the Biot–Savart law work, the Biot–Savart law lacking the necessary longitudinal repulsive force. The large Ampère repulsion between collinear current elements yields the second term in equation (1), varying as $\ln(b/r)$, for the force on Ampère's bridge.

References

Ampère A M 1823 *Mem. Acad. R. Sci.* **6** 175 (*Memoires sur l'Electrodynamique* 1882 (Paris: Gauthier Villars) vol. 1 p 25)
Peoglos V 1988 *J. Phys. D: Appl. Phys.* **21** 1055
Wesley J P 1983 *Bull. Am. Phys. Soc.* **28** 1310
—— 1987 *Spec. Sci. Tech.* **10** 47