



Reply to Comment on ‘Modelling the magnetic dipole’

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Reply to Comment on ‘Modelling the magnetic dipole’

Kira Seleznyova^{1,2}, Mark Strugatsky² and Janis Kliava¹

¹ LOMA, UMR 5798 Université de Bordeaux CNRS, F 33405 Talence cedex, France

² Physics and Technology Institute, Crimean Federal V.I. Vernadsky University, Simferopol, Republic of Crimea

Abstract

The claim that the model of a pair of fictitious magnetic charges, described in our recent paper, is that of an infinitely thin solenoid is a mistake, mainly based on misinterpretation of certain figures therein.

The comment [1] claims that the model of ‘a pair of fictitious magnetic charges’, introduced and described in our recent paper [2], is in fact that of an infinitely thin solenoid. (We may add that the latter model is exactly analogous to that of an infinitely thin permanent magnet.) Below we show that this claim is based on a misunderstanding.

The affirmation that in order to produce a spherically-symmetric magnetic field, ‘one *must* assume that it arises from one end of a thin long solenoid’ [2], is misleading; indeed, one *can* as well assume that it arises from a magnetic monopole. Of course, the Dirac vector potential of the magnetic monopole, cf equation (23) in our paper [2] and equation (3) in the comment [1], has a singularity along the half-line $\vartheta = \pi$. In our paper we clearly specify this flaw (to readers particularly interested in this issue, the so-called Dirac string, we can recommend the detailed analysis by Hadjesfandiari [4]).

Meanwhile, it is a mistake to affirm that ‘the authors... introduce two such fields of opposite sign *with the singularity on the line between them*’ [1]. In fact, in order to calculate the magnetic field in this model, we start with the vector potential of a *pair* of magnetic monopoles of opposite sign, cf equations (23), (24) in our paper. This vector potential has singularities only at the locations of both magnetic monopoles and *not* on the line between them (as explicitly emphasized in our paper). As a consequence, the magnetic field can readily be calculated in the whole space, *including the dipole axis*.

In order to examine the claim that ‘they are not describing a dimonopole model of the magnetic dipole, but in fact an infinitely thin solenoid of finite length’ [1], one must understand the difference between the two models in question. Gsponer [3] indicates one fundamental difference concerning the form of the $\sim\delta(r)$ singularity of the magnetic field at the space origin; however, this issue is irrelevant for the present discussion. Elsewhere, both models yield identical results, except on the dipole axis (chosen as the z -axis). The magnetic

field \mathbf{B} inside a solenoid (or a permanent magnet) is directed from the south pole to the north; thus, if the magnetic moment is oriented along the *positive* direction of the z -axis, the z -component of the magnetic field, B_z , between the poles would be *positive*. In contrast, in the model of a pair of ‘magnetic charges’ the magnetic field on the dipole axis is directed from the positive charge to the negative one; thus, on the portion of the z -axis between the two charges B_z is *negative*. (The radial component of \mathbf{B} vanishes on the dipole axis.) Indeed, putting $\vartheta = 0$ or π in the second equation (26) of our paper yields, for $-\frac{1}{2}d < z < \frac{1}{2}d$, an obviously *negative* result, as expected for a pair of fictitious magnetic charges

$$B_z(\vartheta = 0, \pi) = -\frac{2\mu_0 m}{\pi d} \frac{d^2 + 4z^2}{(d + 2z)^2(d - 2z)^2} < 0.$$

(Here m is the dipole magnetic moment, and the positive and negative monopoles are located on the z -axis at $z = +\frac{1}{2}d$ and $z = -\frac{1}{2}d$, respectively.)

Finally, there are no ‘puzzling features’ [1] in figures 5 and 6 in our paper [2]; indeed, it is *not* true that the field lines in these figures are ‘both entering and leaving’ the two monopoles.

In fact, the field lines in these figures are represented by *thin* lines, and it is clearly seen that all of them are leaving the positive monopole and entering the negative one, as expected. On the other hand, the *thick* arrows connecting the monopoles in these figures are merely symbolic representations of the dipole moment. Apparently, these arrows have been mistaken for field lines, in spite of the obvious difference in the graphical notation.

Clearly, an infinitely thin solenoid (or permanent magnet) also can serve as a model of the magnetic dipole. Meanwhile, in the framework of our paper this model would have been redundant, since its description would be too similar to that of the uniformly magnetized sphere, introducing two distinct vector potentials, one inside and other outside the field source, cf equation (15) in [2]. Besides, from the viewpoint of teaching the model of a pair of fictitious magnetic charges is clearly more attractive because of its closeness to the model of an electric dipole. Note that in the electro/magnetostatics cursus the magnetic dipole is usually taught after the electrical dipole and, certainly, before the solenoid and, *a fortiori*, magnetic solids.

References

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