Ogrin, Petrov, and Winlove Reply: In this Letter [1] we reported a theoretical model of a microscopic magnetic device capable of producing directional motion in liquids at low Reynolds number. The device is based on two particles with different magnetic properties connected by an elastic spring. Further investigation has revealed an error in the numerical model employed. The torques in the system were significantly underestimated leading to errors in calculating the rotational displacement of the particles. Here we present a corrected version which will also clarify the critical points raised by Vilfan and Stark [2].

After correcting the programming error, it was found that for the parameters employed in Figure 2 of the original Letter the dipole-pair rotates around a fixed point in space. This is in agreement with Ref. [2]. Clearly, the hydrodynamic interactions between the two magnetic particles have a decisive contribution for breaking the symmetry and generating a translational displacement, as suggested by Vilfan and Stark [2]. To demonstrate the effect of the hydrodynamic interactions we used the following approximate expression which can be derived considering the flow past a moving sphere in a viscous fluid [3]:

\[
\ddot{m}_j \mathbf{a}_j = \mathbf{F}^\text{ext}_j - \gamma_j \left[ \mathbf{v}_j - \frac{3}{4} \frac{R_k}{L_{jk}} (\hat{\mathbf{n}}_{jk} \hat{\mathbf{n}}_{jk} + \mathbf{I}) \cdot \mathbf{v}_k \right]
\]  

where \(j, k = 1, 2\) and \(j \neq k\) denote each magnetic bead, \(\ddot{m}_j\) is the particle mass, \(\mathbf{a}_j\) is its acceleration, \(\mathbf{F}^\text{ext}_j\) is the sum of the external forces acting on the particle, \(\gamma_j = 6 \pi \eta R_j\) as defined in [2], \(\mathbf{v}_j\) is the particle velocity, \(R_k\) is the particle radius, \(L_{jk}\) is the interparticle separation and \(\hat{\mathbf{n}}_{jk}\) is the unit vector in the direction connecting the two particles. The external forces acting on each particle are the same as detailed in the original model [1]. The hydrodynamic interaction between the two beads is accounted for by the last term in Eq. (1). The inertial term on the left-hand side of Eq. (1) can be effectively neglected, as the motion of the swimmer is overdamped for physically reasonable values of the parameters.

This model displays a variety of behaviors including directional displacement of the system (i.e., swimming). Figure 1 shows the trajectories of the two particles and their center of reaction (as defined in [2]). Both the speed of translational displacement of the swimmer and its swimming efficiency vary as a function of the parameters of the system. We note that the corrections to the model presented here obviously do not affect the reported swimming of the experimental prototype [1]. The model is also able to predict qualitatively other swimming features observed in the experiment such as the variation in the direction of swimming with change in frequency and amplitude of oscillation.

In summary, we agree with the conclusion of the authors of the Comment [2] about the importance of the hydrodynamic interactions. Nevertheless, the model offers a viable mechanism for producing low Reynolds number swimmers, as also acknowledged by Vilfan and Stark [2].

We are indebted to Andrew Gilbert (EMPS, University of Exeter) for many helpful discussions.

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Received 30 September 2008; published 3 November 2009
DOI: 10.1103/PhysRevLett.103.199802
PACS numbers: 47.63.mf, 45.40.Ln, 87.19.rs, 87.19.ru

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