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Stable doublets of charged microparticles settling under gravity in a viscous fluid

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Can arrangements of particles be held together by static electricity? Samuel Earnshaw, a British mathematician, proved in 1842 that no stationary arrangement of particles in a vacuum can be stable. An informal reading of this theorem, nowadays associated with Earnshaw's name, is that electrostatic interactions are inherently destabilizing. We found that putting charged particles in a fluid can give rise to a different behavior. Stable configurations of uncharged particles are not found in fluids. However, we discovered theoretically stable configurations of charged microparticles in a viscous fluid. Using the point-particle model, we have shown analytically that charged microparticles settling under gravity in an unbounded, electrically neutral fluid can spontaneously rearrange their positions to form stable doublets with larger particles over smaller, denser ones [1]. We have found stationary states with the line of the particle centers inclined with respect to gravity or aligned with it.

We have shown that the basin of attraction for each stable stationary state has infinite measure, so that particles can capture one another even when they are very distant, and even if their charge is very small [2]. We have shown that the capturing of charged particles takes place in a large region in the parameter space of the ratio of particle radii and the ratio of the particle densities.

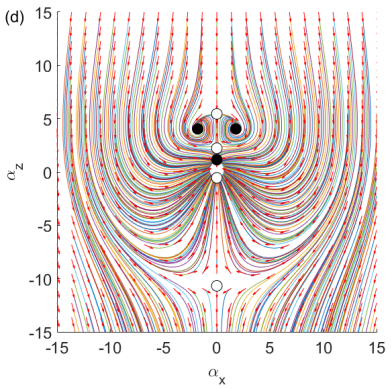

Fig. 1. Example of the relative motion of the larger particle with the origin defined as the center of the smaller particle. The open and filled circles represent, respectively, not stable and stable stationary states [2].

Our investigation of stability in a fluid was inspired by the recent development of modern technologies such as microfluidics, Lab-On-Chip, medical diagnostics, experiments with bacteria or algae, and the design of innovative fluid-based materials and devices - e.g. to carry drugs or treat wastewater. In such systems, particles are often charged and polydisperse.

References

[1] Ch. I. Trombley and M. L. Ekiel-Jezewska, *Phys. Rev. Lett.* **121**, 254502 (2018).
[2] Ch. I. Trombley and M. L. Ekiel-Jezewska, *J. Phys. Commun.* **5**, 075005 (2021).