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Ratcheting of spherical particles in simple microfluidic devices: making particles move against the direction of the net force

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We examine the electrophoresis of charged spherical particles in microfluidic devices made of alternating wells and narrow channels, including a system previously used to separate long DNA molecules. Our computer simulations predict that such systems can be used to separate spherical particles of different sizes that share the same free-solution mobility. Interestingly, the electrophoretic velocity shows an inversion as the field intensity is increased: while small particles have higher velocities at low field, the situation is reversed at high fields with the larger particles then moving faster. The resulting nonlinearity allows us to use asymmetric pulsed electric fields to build separation ratchets: particles then have a net size-dependent velocity in the presence of a zero-mean external field. Exploiting the inversion mentioned above, we show how to design pulsed field sequences that make a particle move against the mean field (an example of negative mobility). Finally, we demonstrate that it is possible to use pulsed fields to make particles of different sizes move in opposite directions even though their charge have the same sign.

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