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Induced-Charge Electro-Osmosis: Theory and Microfluidic Applications

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Induced-charge electro-osmosis (ICEO) involves the nonlinear electro-osmotic slip caused by an applied field E_0 acting on induced ionic charge in the vicinity of a polarizable surface. A simple physical picture is presented, and quadrupolar ICEO flows around conducting cylinders in steady and unsteady electric fields are described, giving perhaps the clearest example of a non-equilibrium electrokinetic phenomena. The ICEO slip velocity scale is $u_s \propto \varepsilon_w E_0^2 L/\mu$, where L is a length scale, and is set up on a time scale $\tau_c = \lambda_D L/D$, where λ_D is the screening length and D is the ionic diffusion constant. Breaking the symmetry of the conductor or field yields even richer behavior: a steady, directed flow can be driven parallel or perpendicular to an AC applied field, and an object can be made that rotates under any AC field. These phenomena naturally suggest microfluidic pumps and mixers that operate without moving parts in low-voltage AC fields.

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