ME 517: Micro- and Nanoscale Processes

Lecture 31: Electrokinetics - II

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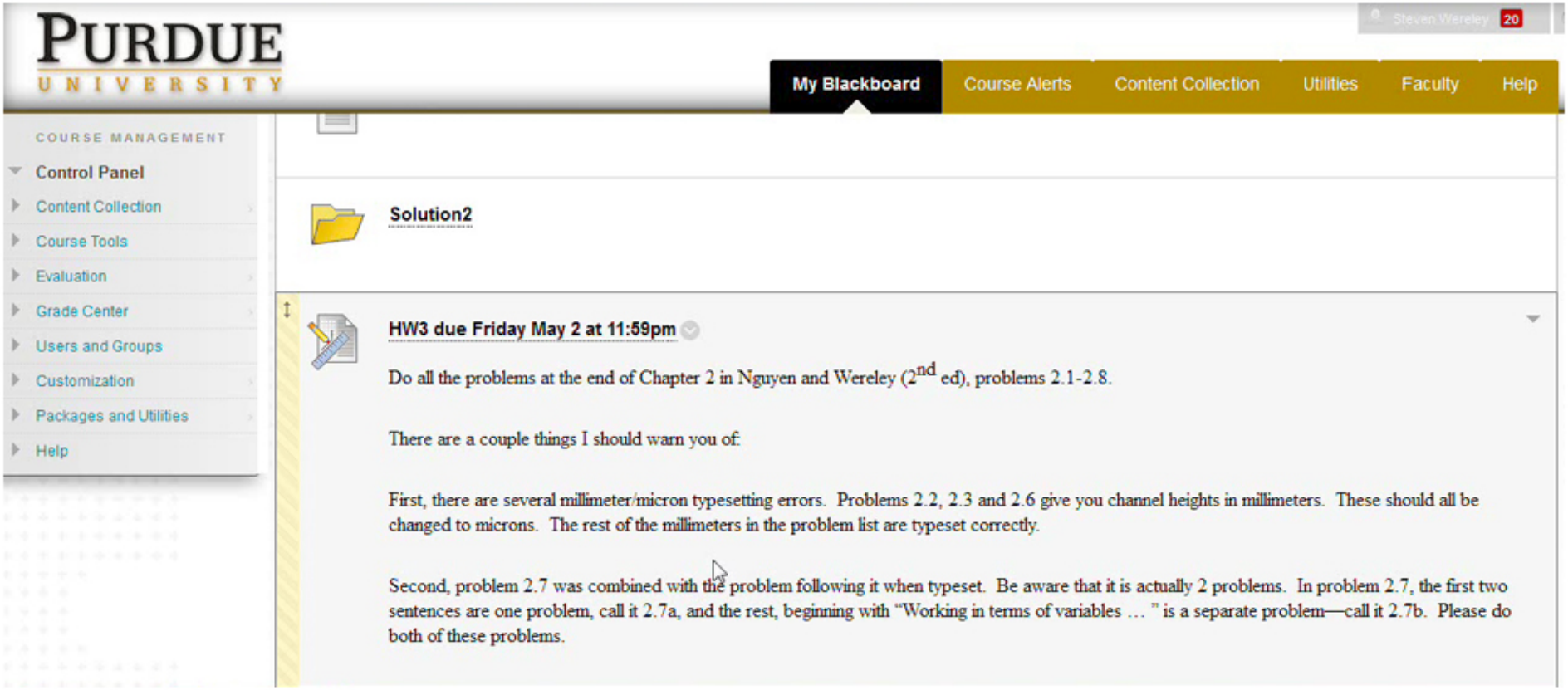
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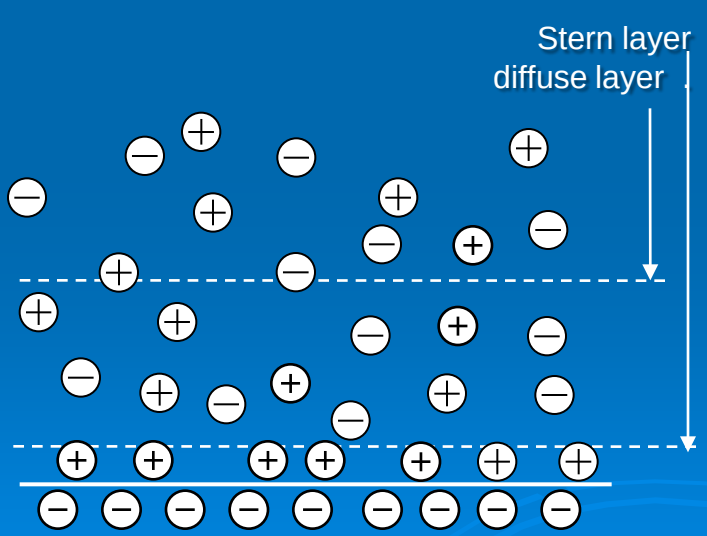
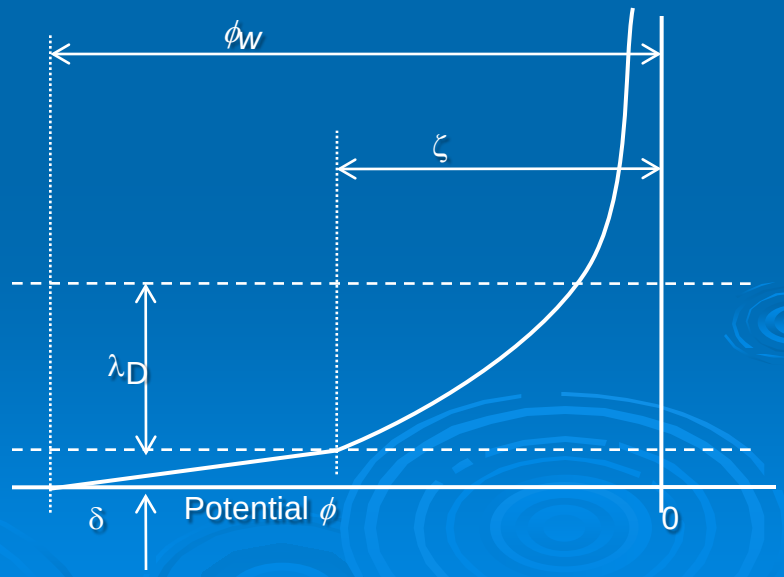
Steven Wereley 20
My Blackboard
Course Alerts
Content Collection
Utilities
Faculty
Help
COURSE MANAGEMENT
Control Panel
Content Collection
Course Tools
Evaluation
Grade Center
Users and Groups
Customization
Packages and Utilities
Help
Solution2
HW3 due Friday May 2 at 11:59pm
Do all the problems at the end of Chapter 2 in Nguyen and Wereley (2nd ed), problems 2.1-2.8.
There are a couple things I should warn you of:
First, there are several millimeter/micron typesetting errors. Problems 2.2, 2.3 and 2.6 give you channel heights in millimeters. These should all be changed to microns. The rest of the millimeters in the problem list are typeset correctly.
Second, problem 2.7 was combined with the problem following it when typeset. Be aware that it is actually 2 problems. In problem 2.7, the first two sentences are one problem, call it 2.7a, and the rest, beginning with "Working in terms of variables … " is a separate problem—call it 2.7b. Please do both of these problems.

Electrokinetics Basics

- Most surfaces acquire surface charge in presence of polar liquid
  - e.g. glass-water
  - many polymers and water, too
  - Debye thickness generally order of nm
  - K = 1.3805×10-23 J/K, F = 9.65 × 10^4 C mol^{-1}, z is valency of ion, c_∞ is bulk concentration, ε is permittivity (8.85418×10^{-12} F/m for vacuum)

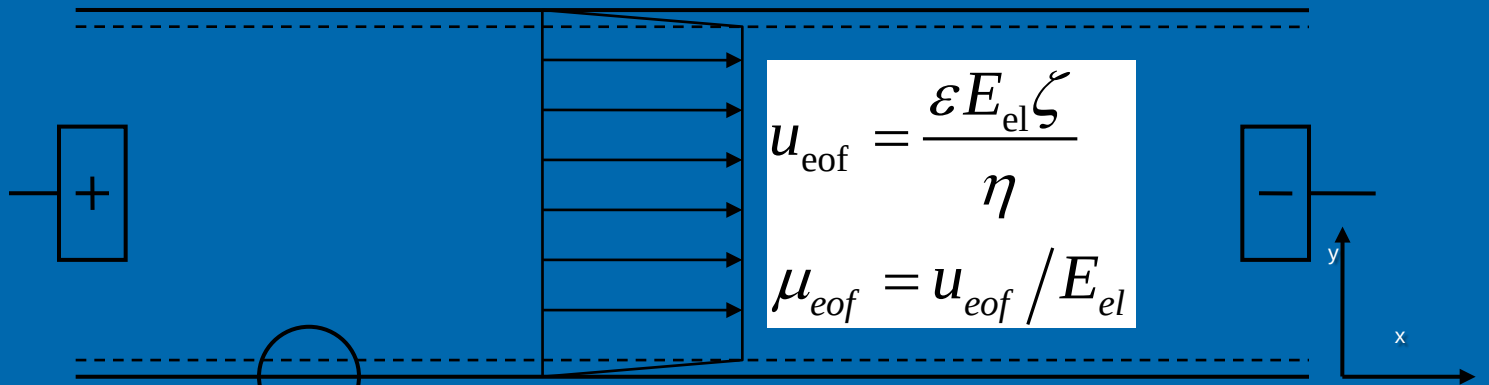
$$\lambda_D = \sqrt{\frac{\varepsilon KT}{2z^2F^2c_\infty}}$$





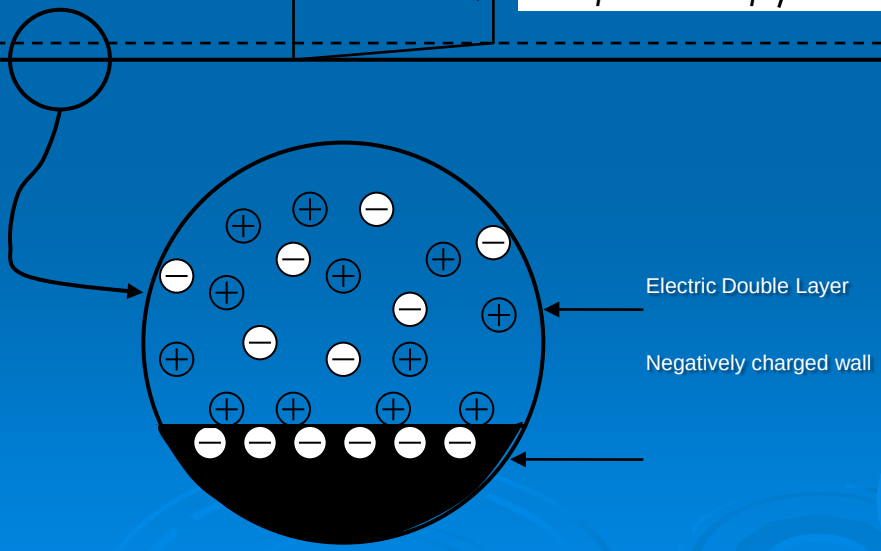
DC Electroosmosis (EOF)

- Apply electrical field across channel
- EDL drawn toward electrode pulling bulk along
- “Plug flow” if no pressure gradient



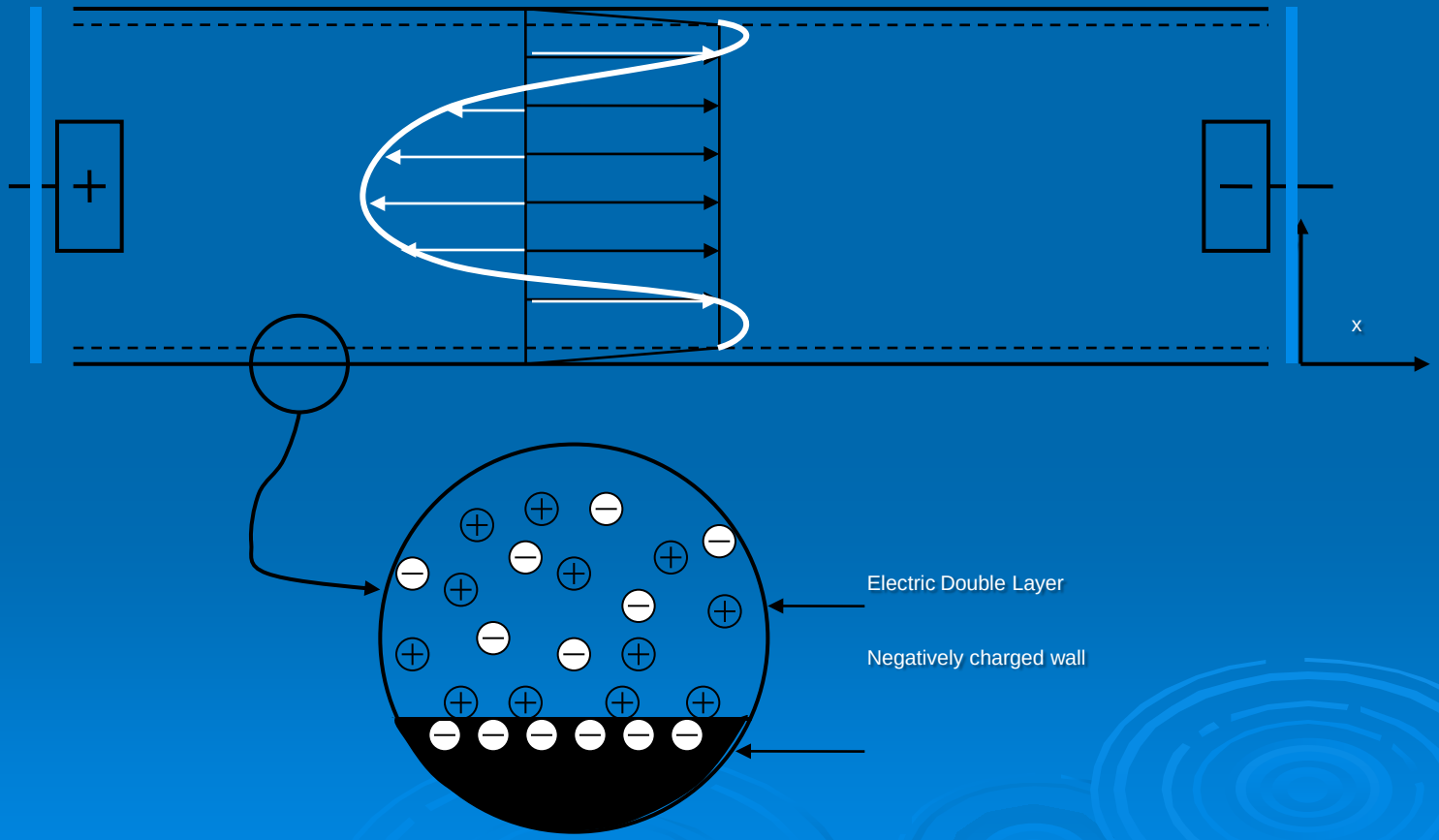
$$u_{\text{eof}} = \frac{\varepsilon E_{\text{el}} \zeta}{\eta}$$

$$\mu_{eof} = u_{eof} / E_{el}$$



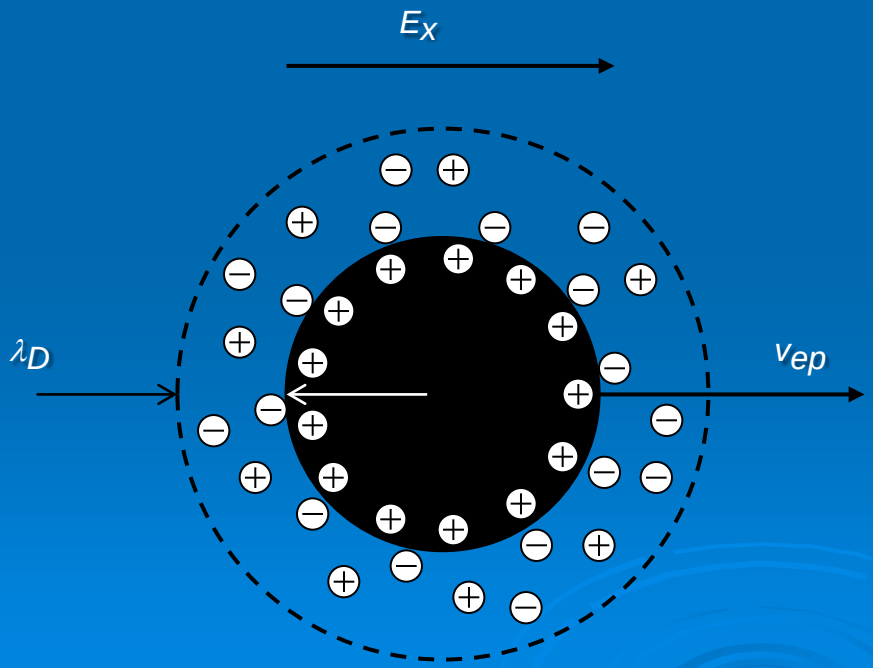
DC Electroosmosis

- Backflow in the presence of pressure gradient
- Zero mean flow in closed channel



DC Electrophoresis (EP)

- Particle/ion manipulation using EDL and electrical field
  - Common technique called ‘capillary electrophoresis’ (CE) used to sequence DNA, ala OJ Simpson or Human Genome Project



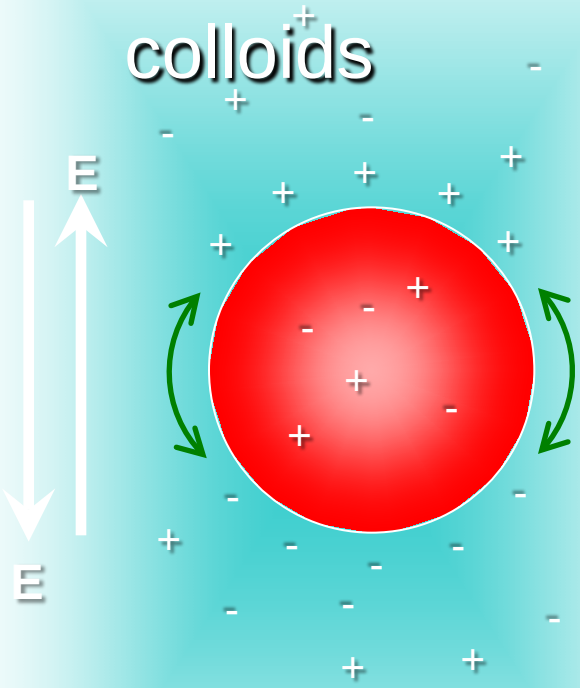
$$u_{\text{ep}} = \frac{2}{3}\frac{\varepsilon\zeta E_{\text{el}}}{\mu}, \lambda_D \gg d_p$$

$$u_{\text{ep}} = \frac{\varepsilon\zeta E_{\text{el}}}{\mu}, \lambda_D \ll d_p$$

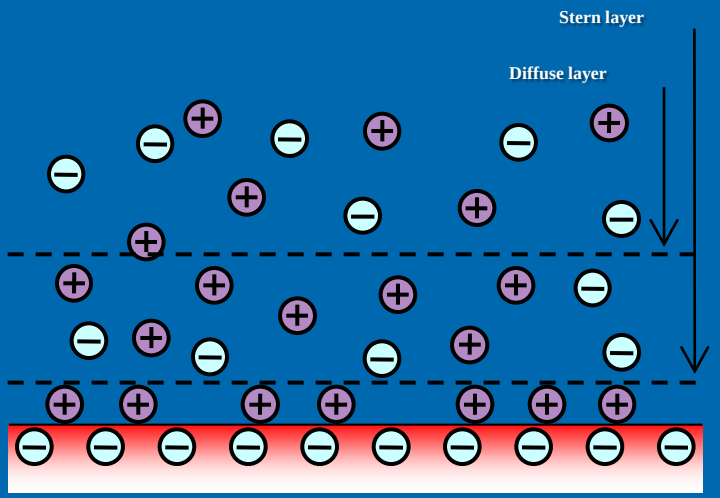
$$\mu_{ep} = u_{ep} / E_{el}$$

Particle Electrokinetics

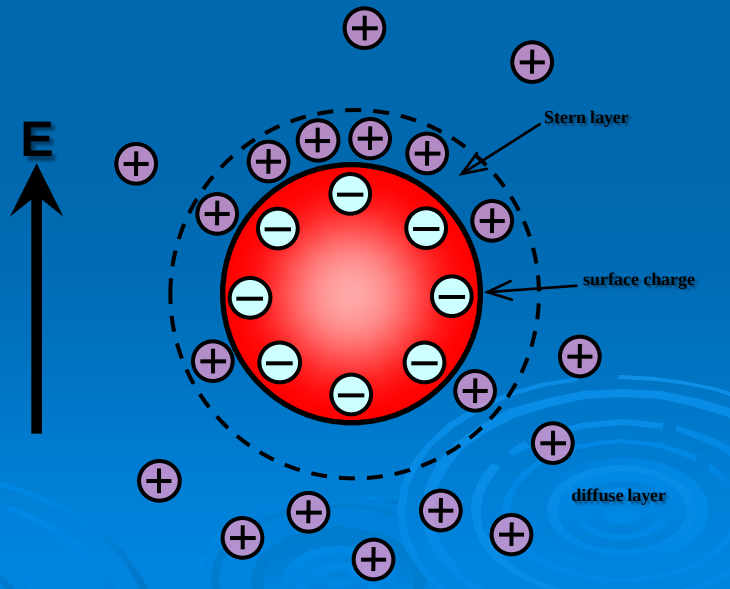
- Polarization of colloids



Relaxation at high AC frequencies



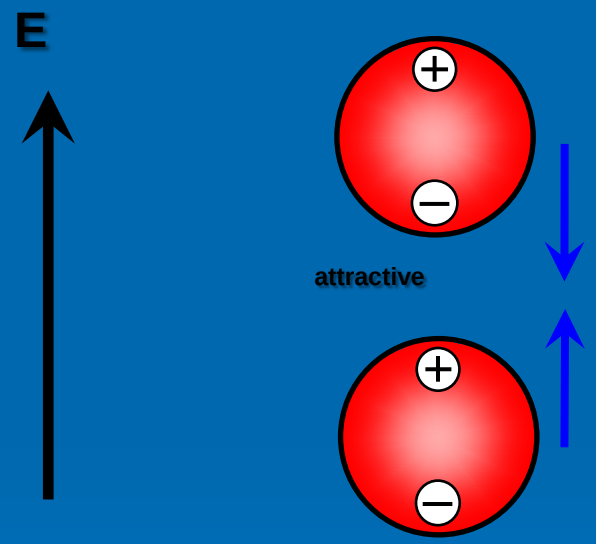
Electric Double Layer polarization



Lyklema, J., *Fundamentals of Interface and Colloidal Science, vol. 2* (1995)

Interparticle Forces

- Dipole-Dipole Interactions



'Pearl Chaining'

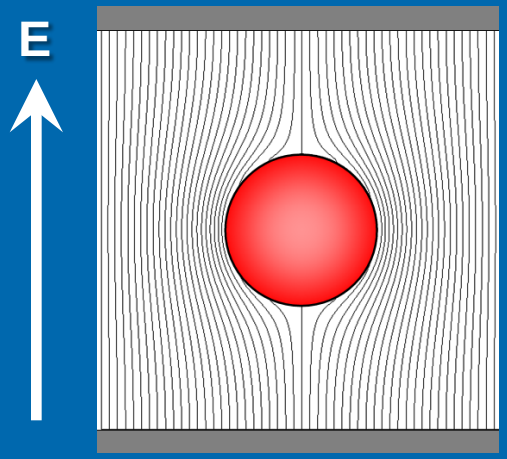
Dipole-Dipole repulsive force

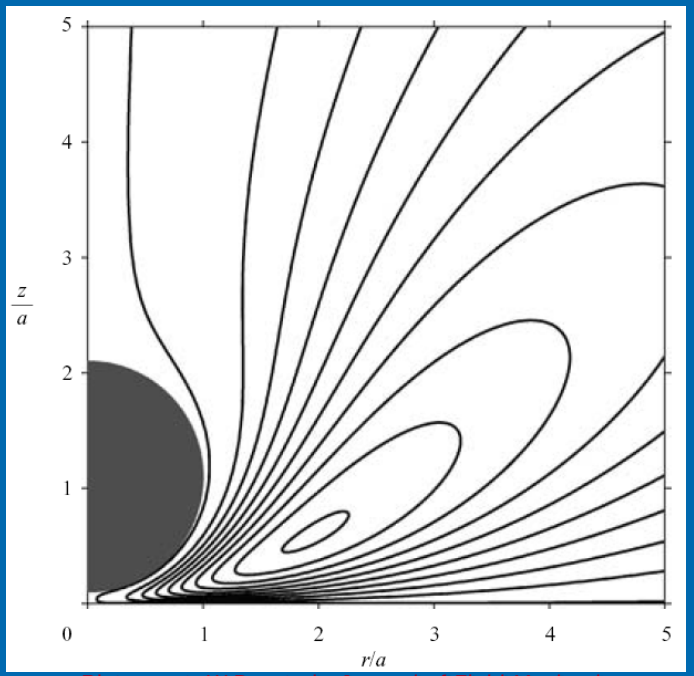
$$F = 3\pi\varepsilon_{\mathrm{m}} a^6 E_o^2 / r^4$$

Nadal, F., et al., *Phys. Rev. E* (2002)

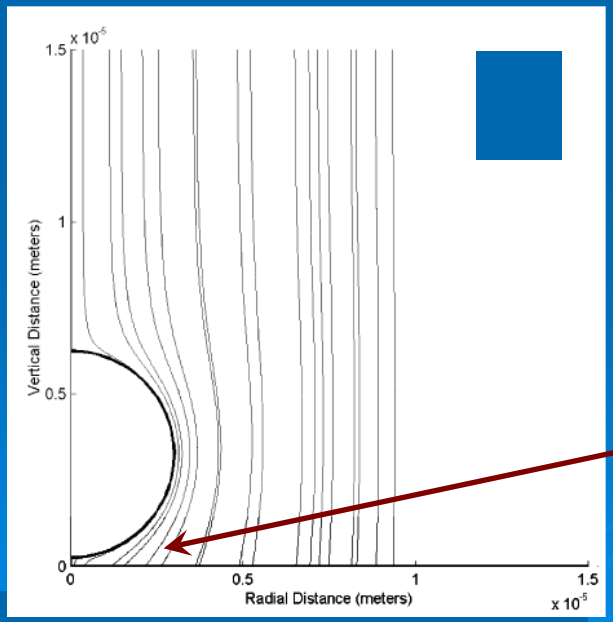
Background: AC Electrokinetics

- Particles themselves will alter electric field





Ristenpart, W.D., et al., *Journal of Fluid Mechanics* (2007)

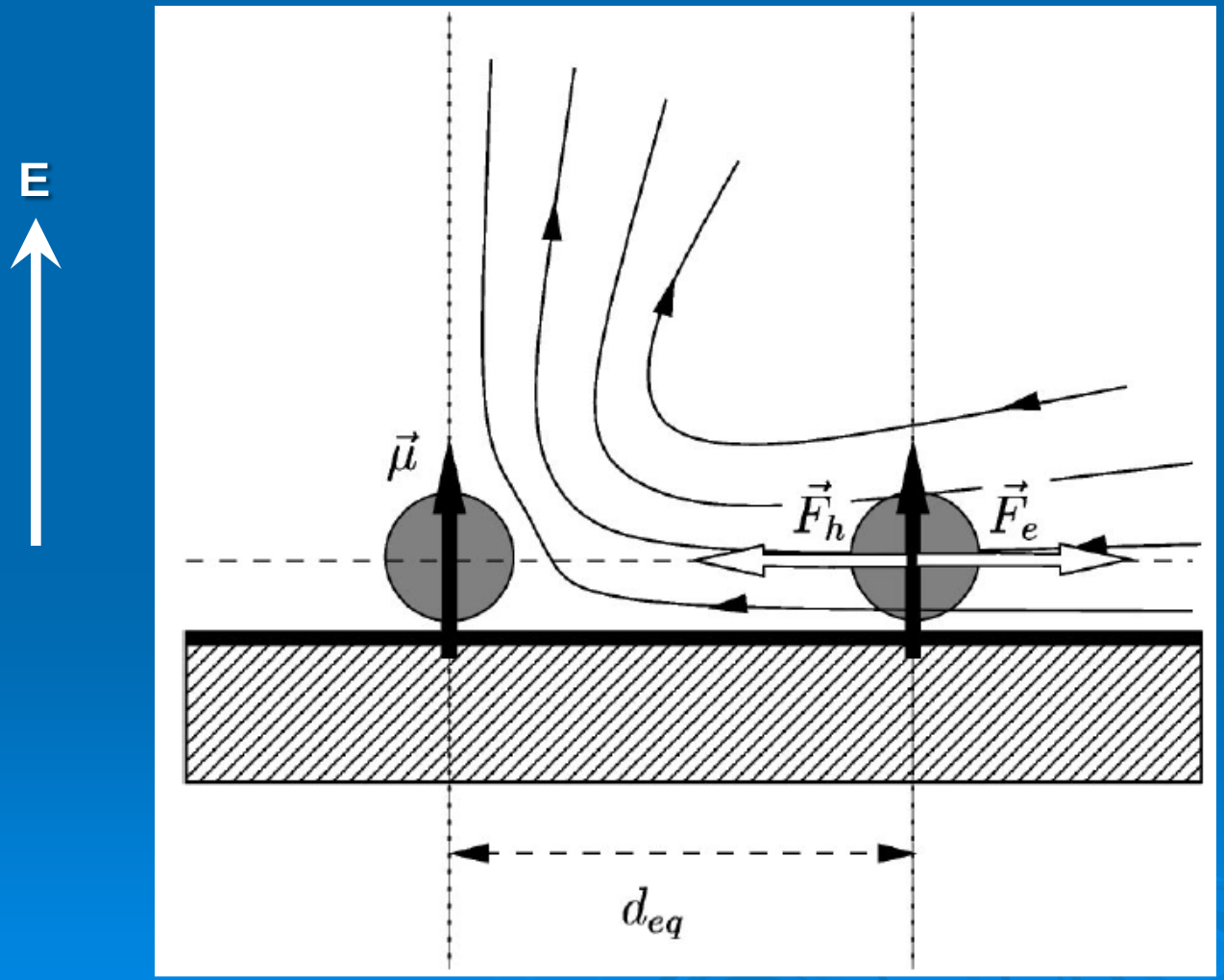


Fagan, J. A., et al., *Langmuir* (2004)

- Distortion leads to a tangential component of the electric field over the electrode surface.
- This generates electrohydrodynamic flow (ACEO)

Background: AC Electrokinetics

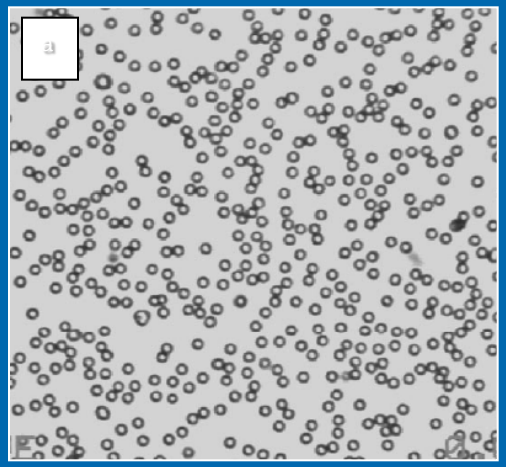
- Particle-Particle interactions



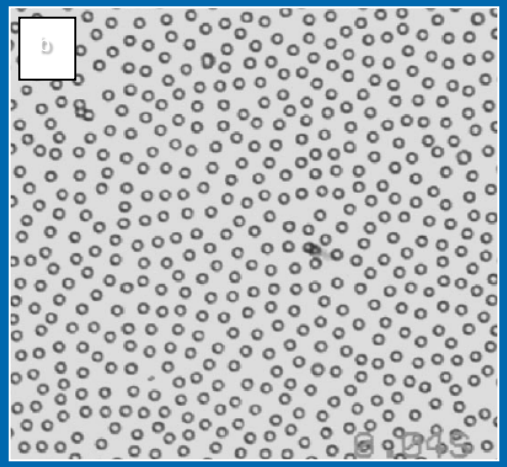
Nadal, F., et al., *Physical Review E.* (2002)

Background: AC Electrokinetics

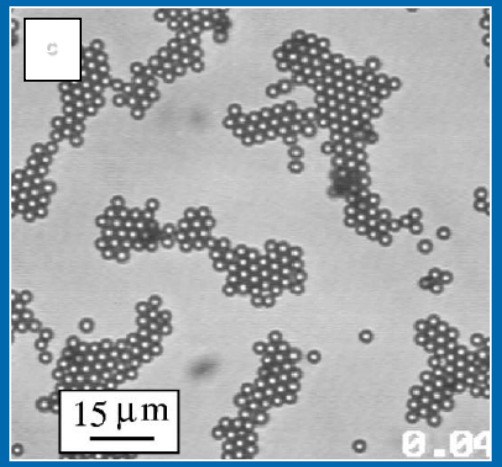
No electric field



f = 2 kHz, E = 185 V cm^{-1}



f = 400 Hz, E = 185 V cm^{-1}



Overcome dipole-dipole repulsive forces at lower frequencies

Assembly of 1.5 µm particles in an aqueous solution of NaOH (10^{-4} M)

Nadal, F., et al., *Physical Review E* (2002)