ROSE-HULMAN Institute of Technology

Departments of Chemistry and Mechanical Engineering

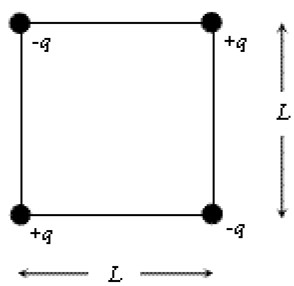
CHEM470, ME497 **Microfluidics**

Homework 6

(Due Tuesday, January 27, 2009)

1. Do you think electro-osmotic flow would work if the solid surface were a metal or some other electrical conductor rather than an insulator like glass? Why or why not?

2. Find the net force on the point charge in the lower left hand corner in the figure below. Express your answer in terms of the length of a side *L* and charge *q*. Be sure to give the *direction* and *magnitude*.



3. As we have seen several times, the Navier-Stokes equations for steady, one-dimensional, fully developed flow in rectangular coordinates reduces to a *linear* ordinary differential equation (ODE) of the form

$$d^2u/dy^2 = f(y)$$

where y is the direction normal to the flow.

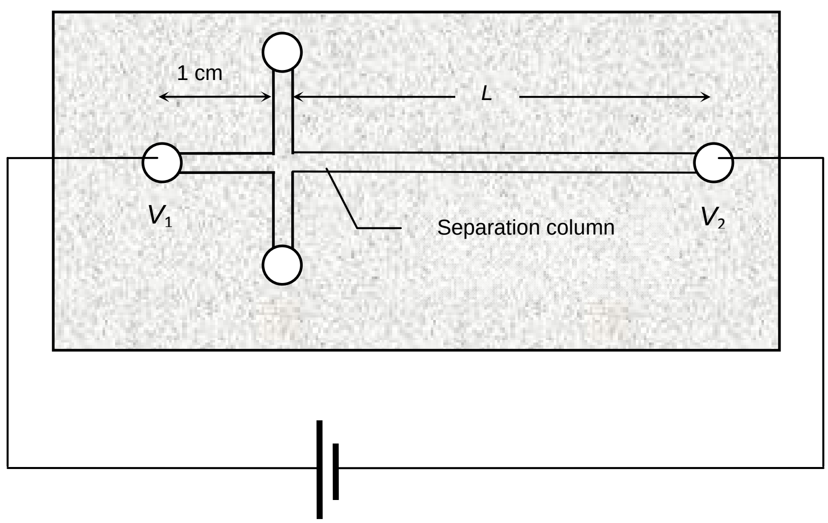
When a constant pressure gradient is applied in the flow direction with no electric-field, $f(y)$ is a constant equal to $(1/\mu)\cdot dP/dx$, resulting in a parabolic velocity profile. When a constant electric-field is applied in the flow direction with no pressure gradient, $f(y) = -(1/\mu)\cdot(\rho_e E_x)$, resulting in an essentially flat profile.

Using what you know about the properties of linear ordinary differential equations, sketch what the velocity profile would look like if both a pressure gradient and an electric-field were applied simultaneously. Sketch what this would look like if the applied pressure gradient were positive instead of the usual negative pressure gradient; i.e., if the flow were in the direction of *increasing* rather than decreasing pressure.[1]

4. Find the Debeye length for a 0.5 molar aqueous solution of KCl.

5. A microfluidic channel of the type shown in the figure is used to separate type A mitochondria with $\mu_{ep,A}$ and type B mitochondria with $\mu_{ep,B}$ contained in a fluid sample.
   a. Due to limitations in the optical detection techniques used in the set-up, a minimum separation distance, d, between the two types of mitochondria is required. Find an expression for the minimum length of the separation column, L, in order to achieve this minimum separation distance.
   b. The properties of the electrolyte and the mitochondria are given below.
      - Electrolyte: $\varepsilon = 7.09 \times 10^{-10}$ C^2/N·m^2, μ (viscosity) = 9.0×10^{-4} N·s/m^2,
      - Mitochondria: $\mu_{ep,A} = -0.80 \times 10^{-4}$ cm^2/V·s, $\mu_{ep,B} = -1.20 \times 10^{-4}$ cm^2/V·s

      Using your results from a., what is the largest (in magnitude) wall potential φ_w (ζ potential) that can be used for an existing channel with d = 1 cm and L = 4 cm?
   c. If the applied voltage in the flow direction is $V_1 - V_2$ = 2000 V, what is the *bulk* fluid velocity in the channel for the wall potential in b)? How long will this separation take, then?



[1] This is what happens in electro-osmotic pumps. The pressure in the fluid is increased across the pump and then sent on its way to flow through some treacherous microfluidic network with all sorts of pressure drops. One nice thing about EO pumps is that they have no moving parts!