Thermoelectric Pumps in charged fluids

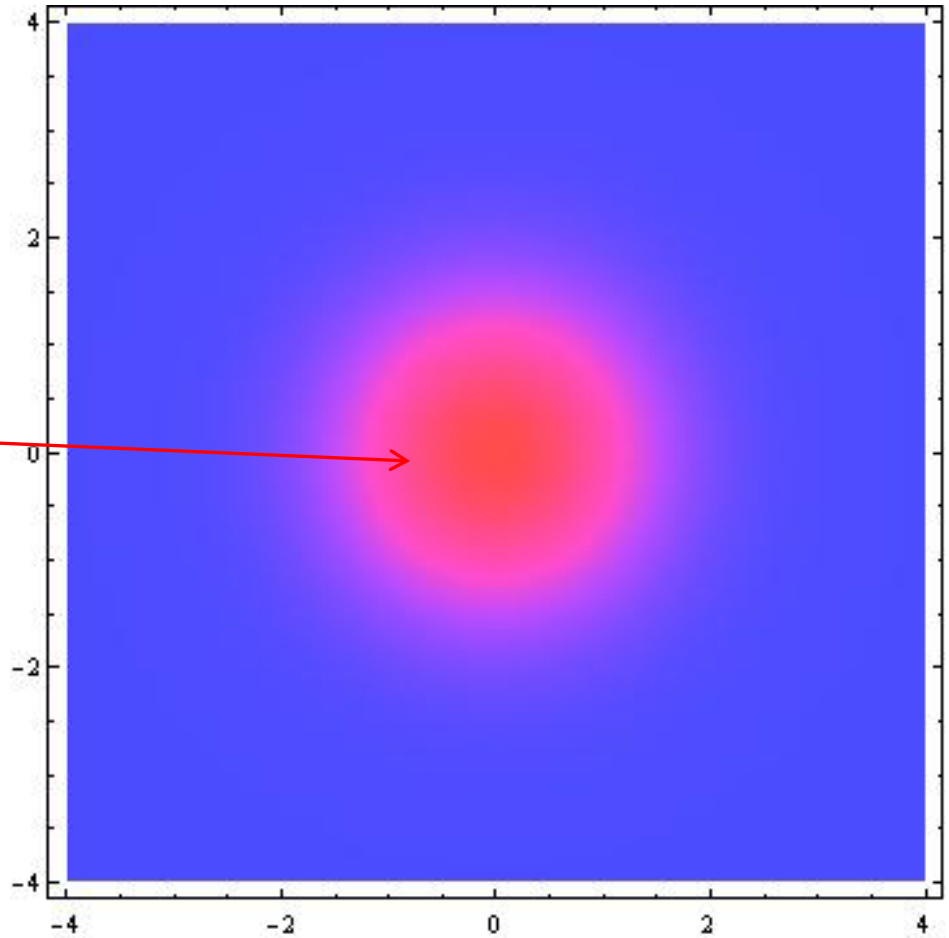
S Nader Rasuli

&

Reza Kiani Iran-Pour

A Focused Laser Beam Heats up Fluid Locally:

The hot spot



$$T(r) = T_0 + \delta T \exp[-\frac{r^2}{2\sigma^2}]$$

A Hot Spot

Ion concentration

$$\vec{J}_i = -D_i \vec{\nabla} C_i + \mu_i q_i \vec{E} C_i - D_i S_{Ti} C_i \vec{\nabla} T$$

$$\vec{\nabla}.\vec{E} = \frac{q_+(C_+ - C_-)}{\varepsilon} = q_+ \frac{\delta C}{\varepsilon}$$

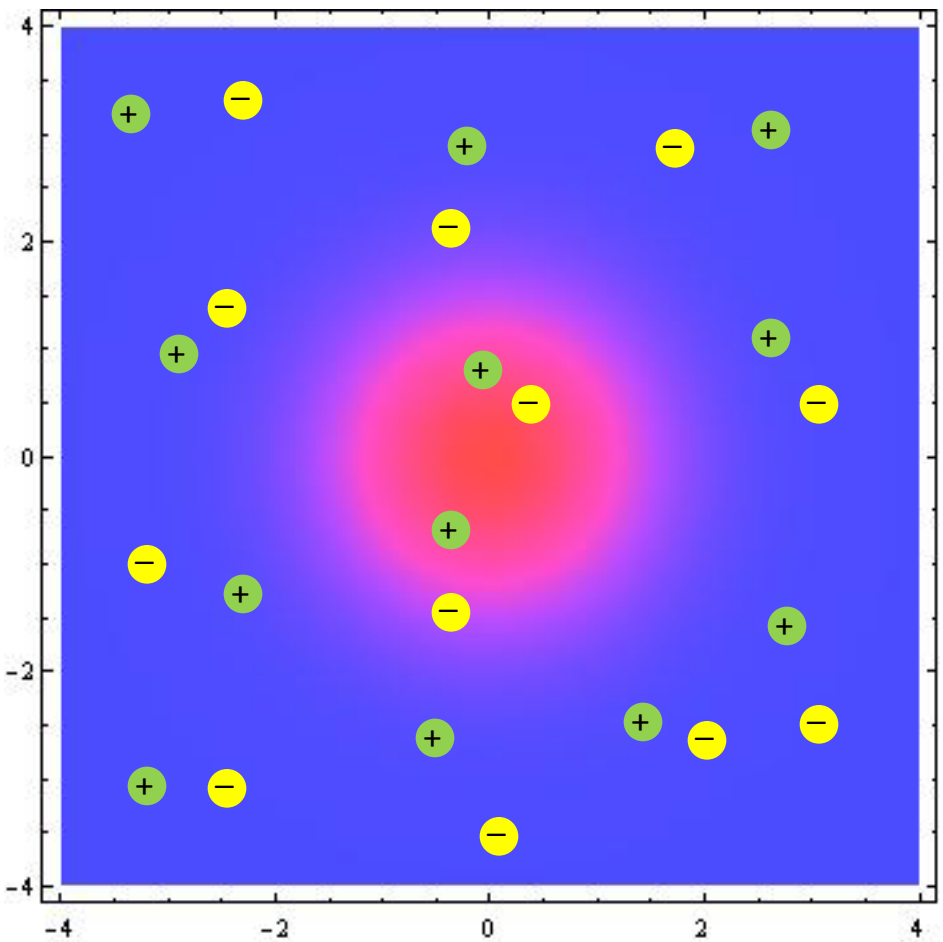
Diffusion Coefficient

mobility

charge

Soret Coefficient

$$\vec{\nabla}.\vec{J}_i = 0$$



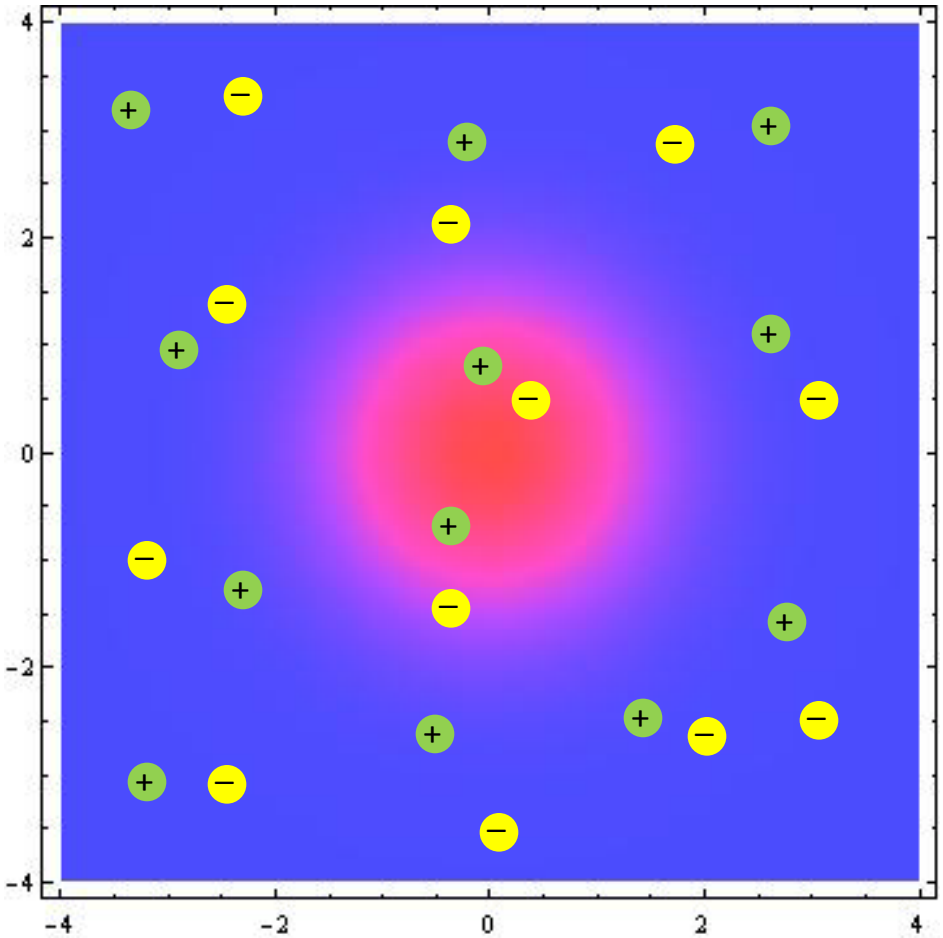
$$T(r) = T_0 + \delta T \exp[-\frac{r^2}{2\sigma^2}]$$

A Hot Spot + Charged Fluid

$$(\nabla^2 - \kappa^2)\,\delta C = -(S_+ - S_-)C_0 \nabla^2 T \quad \Rightarrow \quad \delta C(r) = -(S_+ - S_-)\,\delta T\, C_0\, F(r)$$

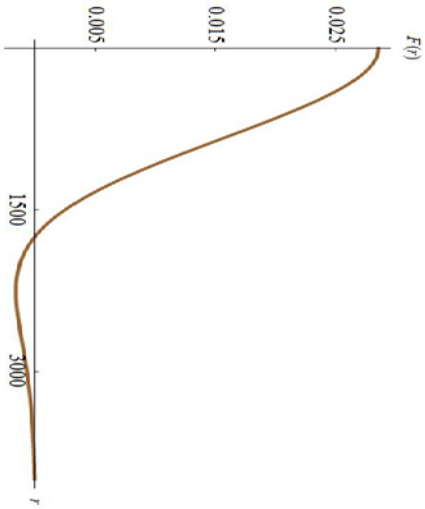
$$\kappa = \sqrt{\frac{2\,q^2 C_0}{\varepsilon\, K_B T}}$$

Ion	$T_0 \times S$
H^+	2.7
Na^+	0.7
K^+	0.5
Li^+	0.1
Cl^-	0.1
OH^-	3.4



$$\kappa = 0.01\, nm^{-1}$$

$$\sigma = 1\mu m = 10^3\, nm$$



$$T(r) = T_0 + \delta T \exp\left[-\frac{r^2}{2\sigma^2}\right]$$

An artificial colloid

$$(\nabla^2 - \kappa^2)\,\delta C = -(S_+ - S_-)C_0 \nabla^2 T \quad \Rightarrow \quad \delta C(r) = -(S_+ - S_-)\,\delta \mathrm{T}\, C_0\, F(r)$$

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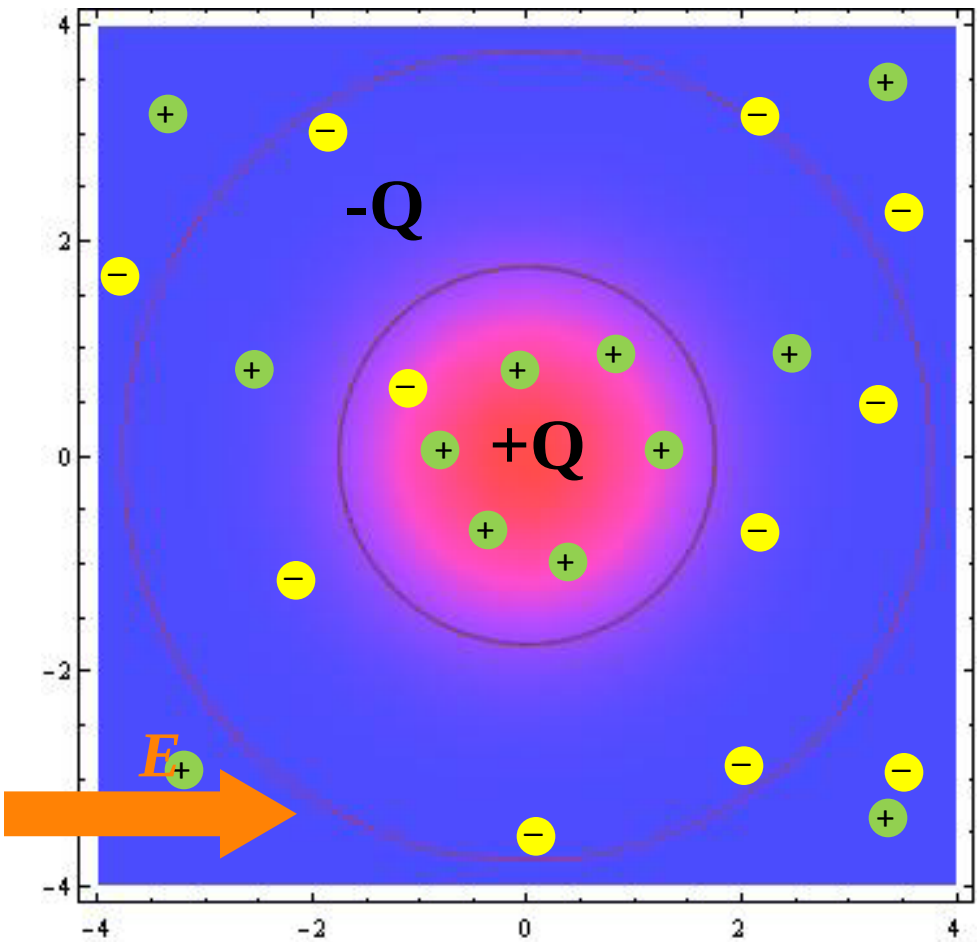

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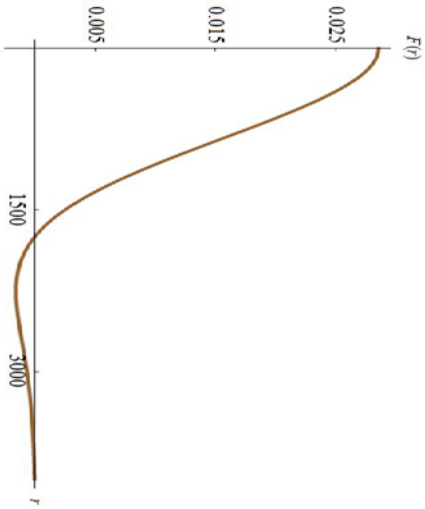


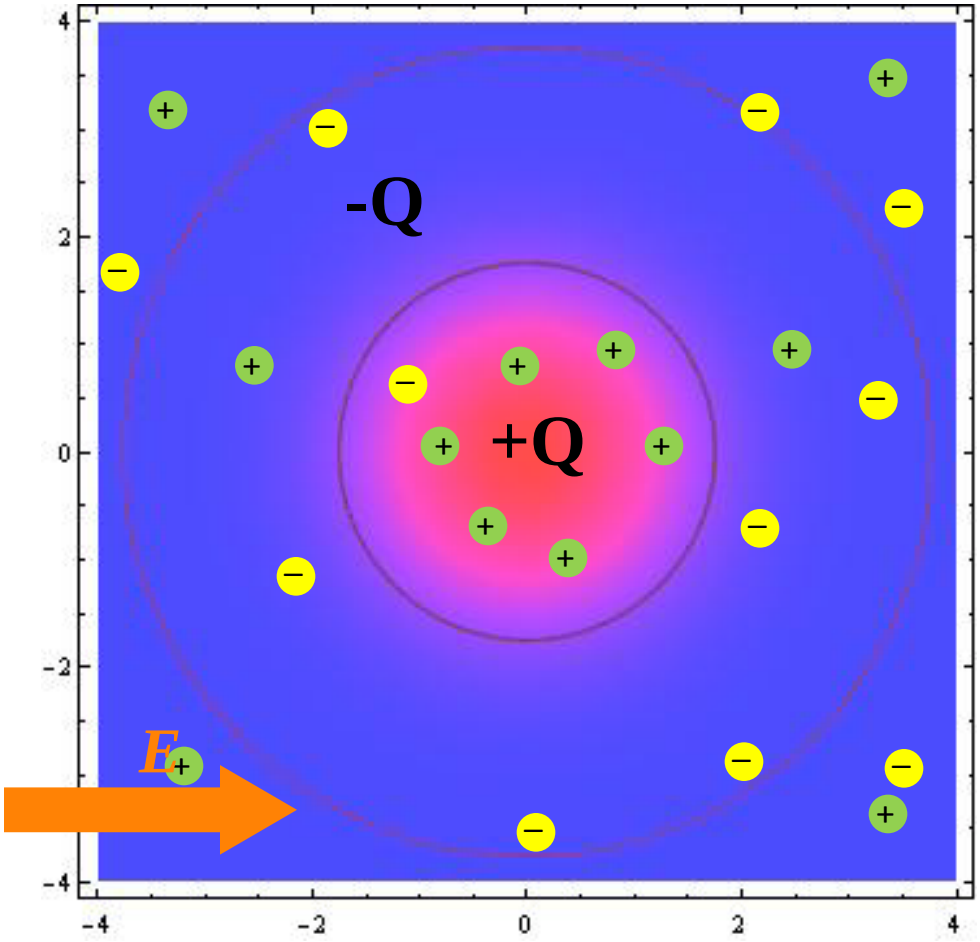
For $\delta \mathrm{T} = 10°C$ and $\kappa = 1\, nm^{-1}$ the gathered charge was estimated as $Q = 2.5 \times 10^{-12}\, C$!

An artificial colloid

$$-\vec{\nabla} P + \eta \nabla^2 \vec{V} + q \vec{E}\, \delta C = 0$$

$$\vec{\nabla}.\vec{V} = 0$$

$$\delta C(r) = -(S_+ - S_-)\, \delta T\, C_0\, F(r)$$



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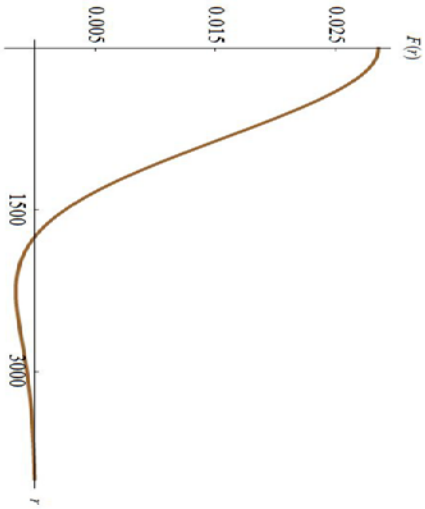

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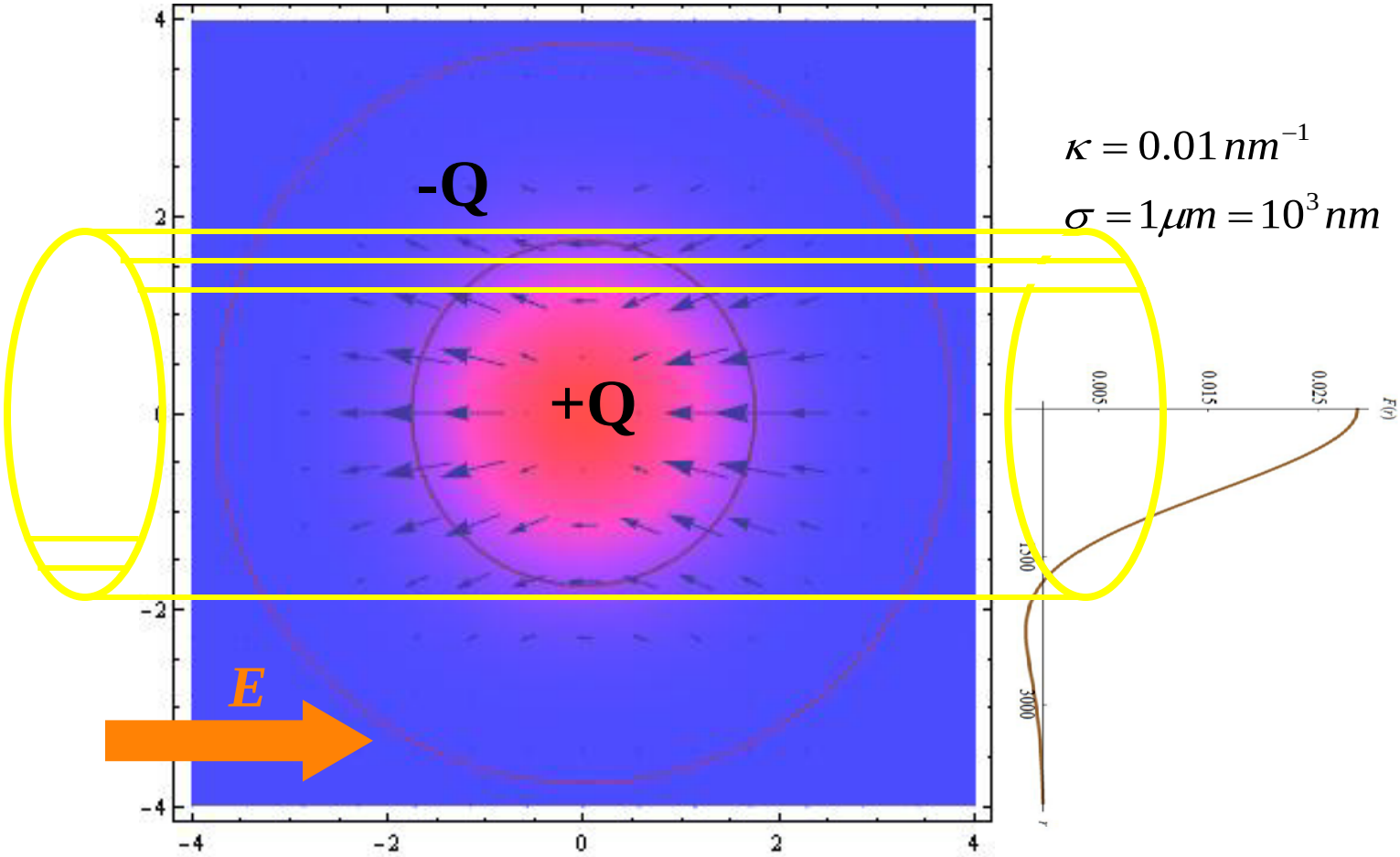

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A Net Current?

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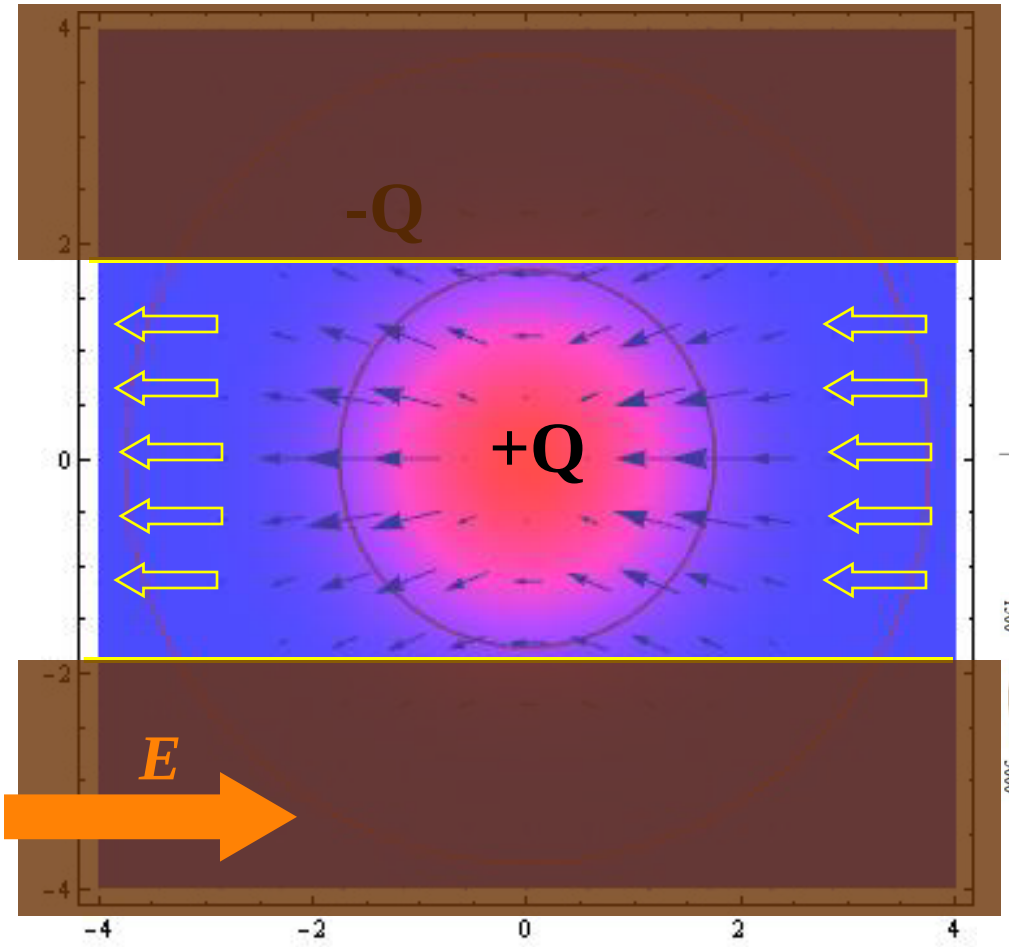

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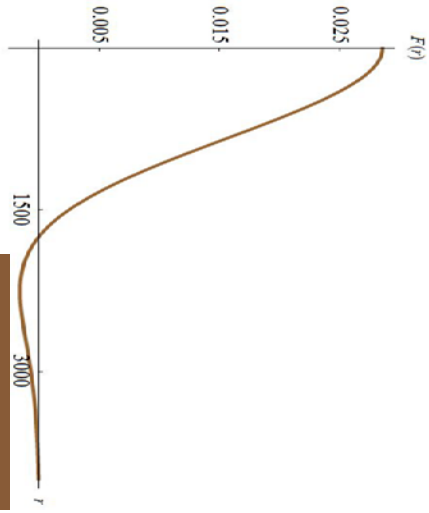
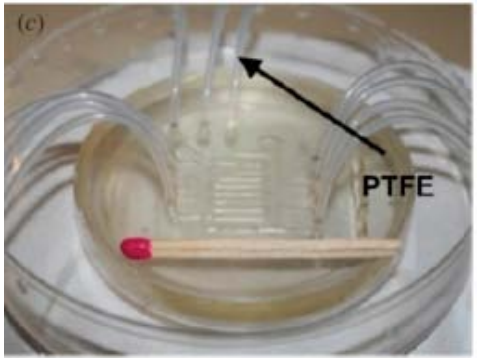
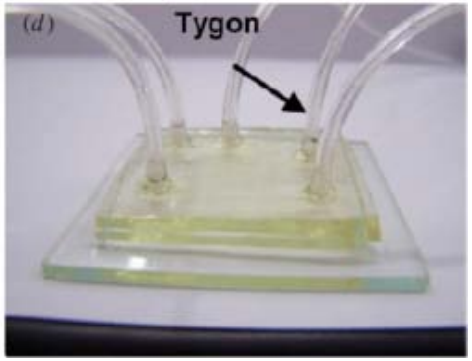
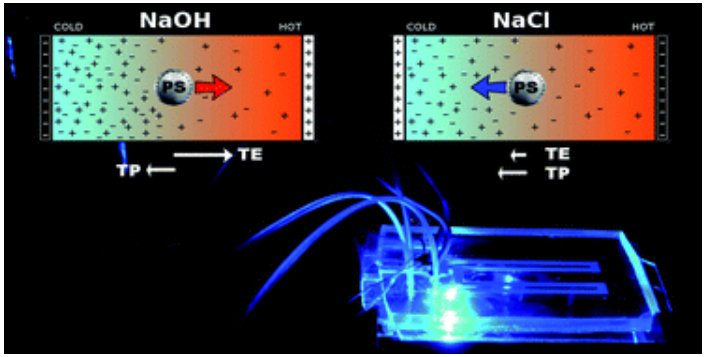
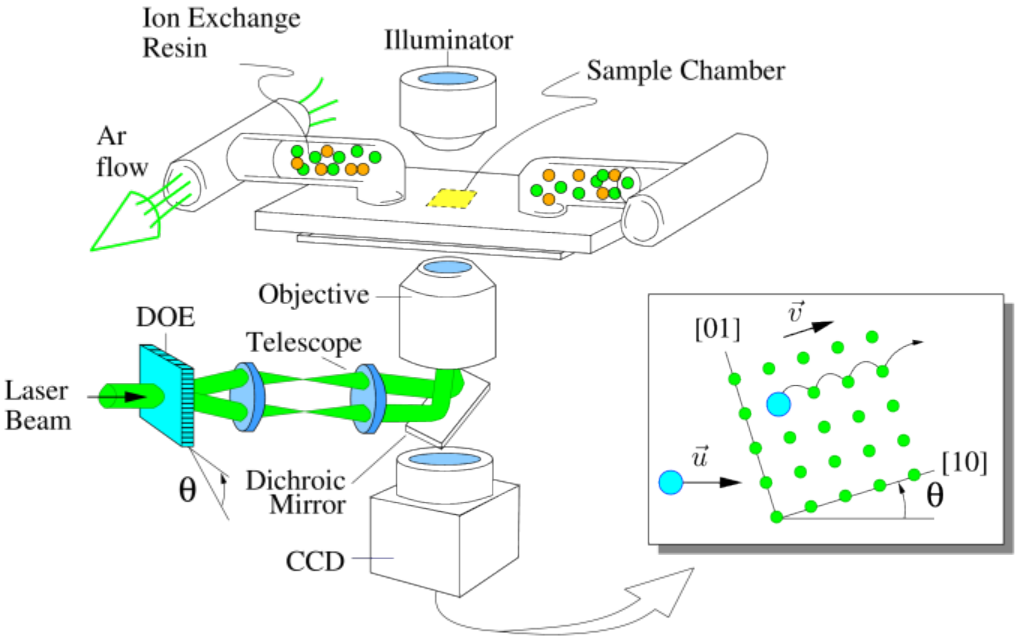


A Pump for Micro/Nano Fluidic Devices:









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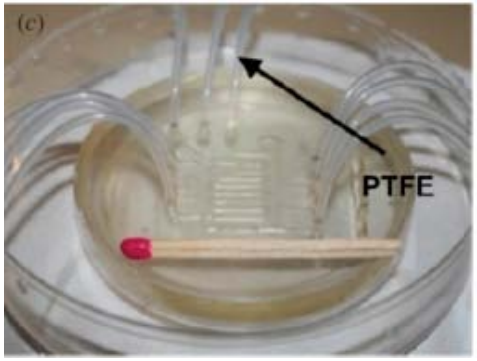

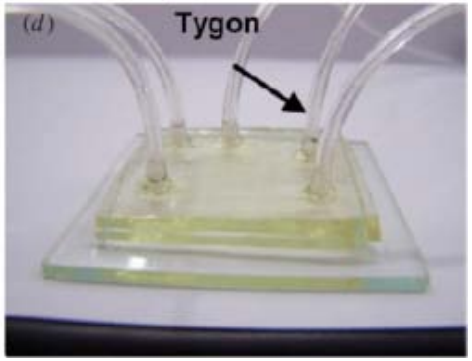

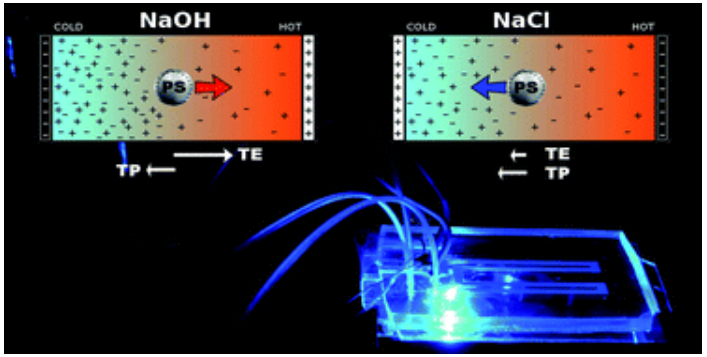

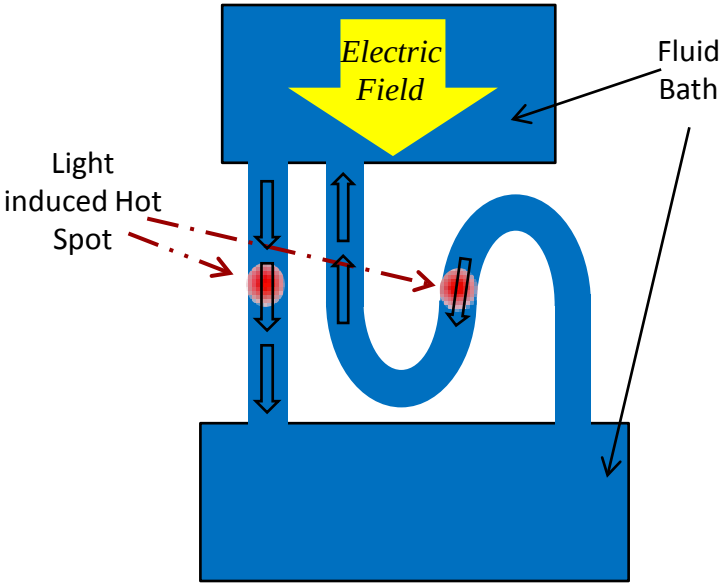

Seek For a Net Current?

$$-\vec{\nabla}\,\mathrm{P}+\eta\nabla^2\,\vec{\mathrm{V}}+q\,\vec{\mathrm{E}}\,\delta C=0$$

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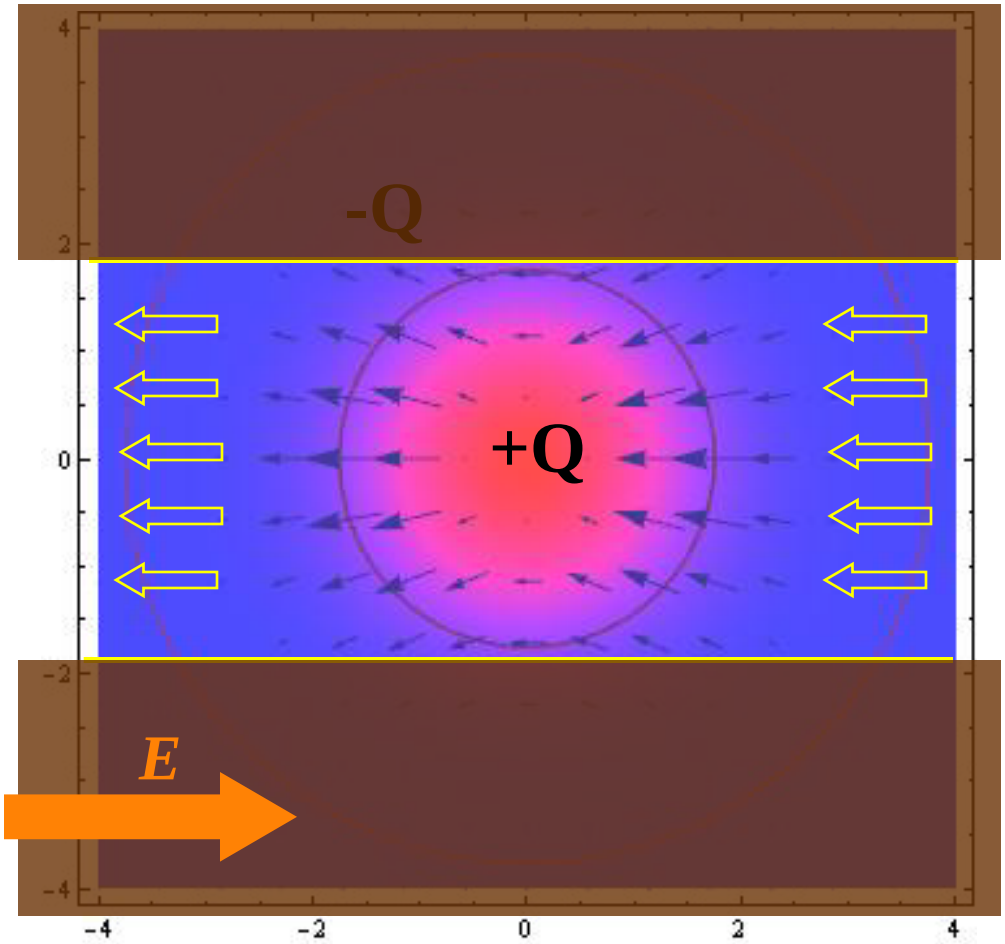
$$\delta C(r)=-(S_+-S_-)\,\delta\mathrm{T}\,C_0\,F(r)$$



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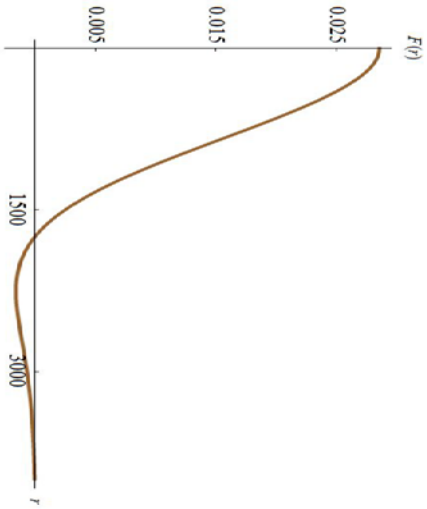


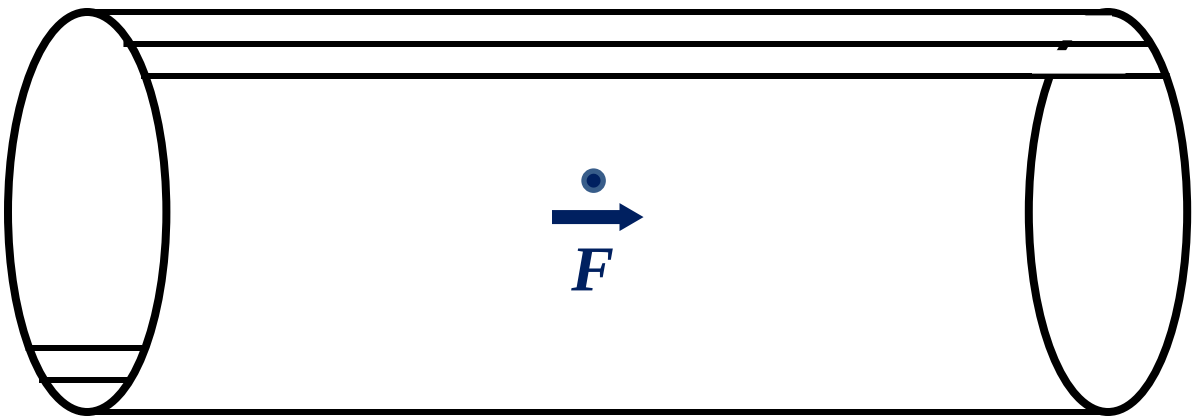
Solving the Equations Inside a Cylinder?

$$-\vec{\nabla} P_G + \eta \nabla^2 \vec{V}_G + F\,\hat{z}\,\delta(\vec{x} - \vec{x}_0) = 0$$

$$\vec{\nabla}.\vec{V}_G = 0$$

$$P_G(\vec{r}, \vec{r}_0) = F \frac{(\vec{r} - \vec{r}_0).\hat{z}}{4|\vec{r} - \vec{r}_0|^3}$$

$$\vec{V}_G(\vec{r}, \vec{r}_0) = \frac{F}{8\pi\eta}\left\{\frac{\hat{z}}{|\vec{r} - \vec{r}_0|} + (\vec{r} - \vec{r}_0)\frac{(\vec{r} - \vec{r}_0).\hat{z}}{|\vec{r} - \vec{r}_0|^3}\right\}$$



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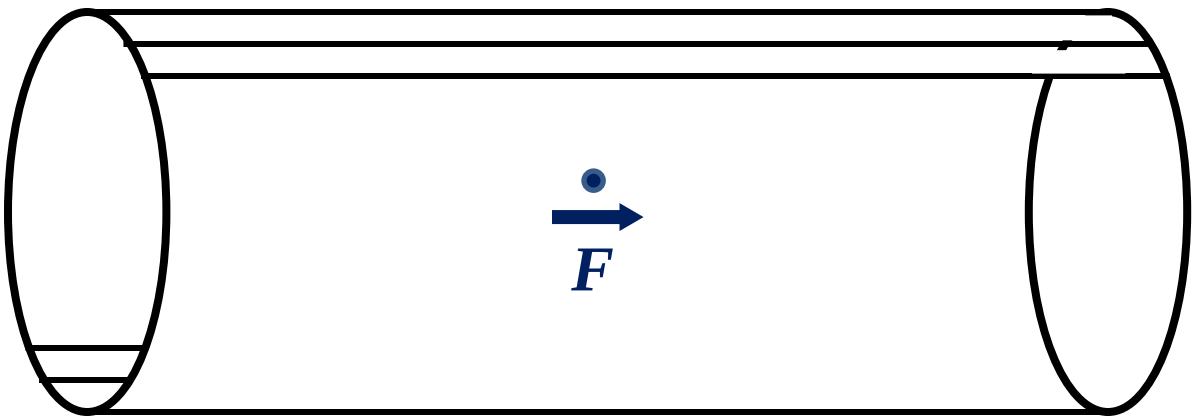
$$P_G(\vec{r}, \vec{r}_0) = F \int_0^\infty dk\, A(k)\, I_0(k\rho)\, \mathrm{Sin}(kz)\, dk$$

$$\vec{V}_{GZ}(\rho, z, 0, 0) = \frac{F}{8\pi\eta} \int_0^\infty \{ \frac{A(k)}{2k} [\, I_0(k\rho) + k\rho\, I_1(k\rho)\,] + \Phi(k)\, I_0(k\rho) \}\, \mathrm{Cos}(kz)\, dk$$

$$+ \frac{F}{4\pi\eta\sqrt{2\pi}} \int_0^\infty \{ [\, 2K_0(k\rho) - k\rho\, K_1(k\rho)\,] \}\, \mathrm{Cos}(kz)\, dk$$



$$A(k) = \frac{-4k^2 R\,[\, I_2(kR)\, K_0(kR) - I_1(kR)\, K_1(kR)]}{\pi\{kR\, I_0(kR)^2 - 2\, I_0(kR) I_1(kR) - kR\, I_1(kR)^2\}}$$

$$\Phi(k) = \frac{2kR\,[\, 1 - I_2(kR)\, K_0(kR) - I_1(kR)\, K_1(kR)]}{\pi\{kR\, I_0(kR)^2 - K_1(kR) I_1(kR) - kR\, I_1(kR)^2\}}$$

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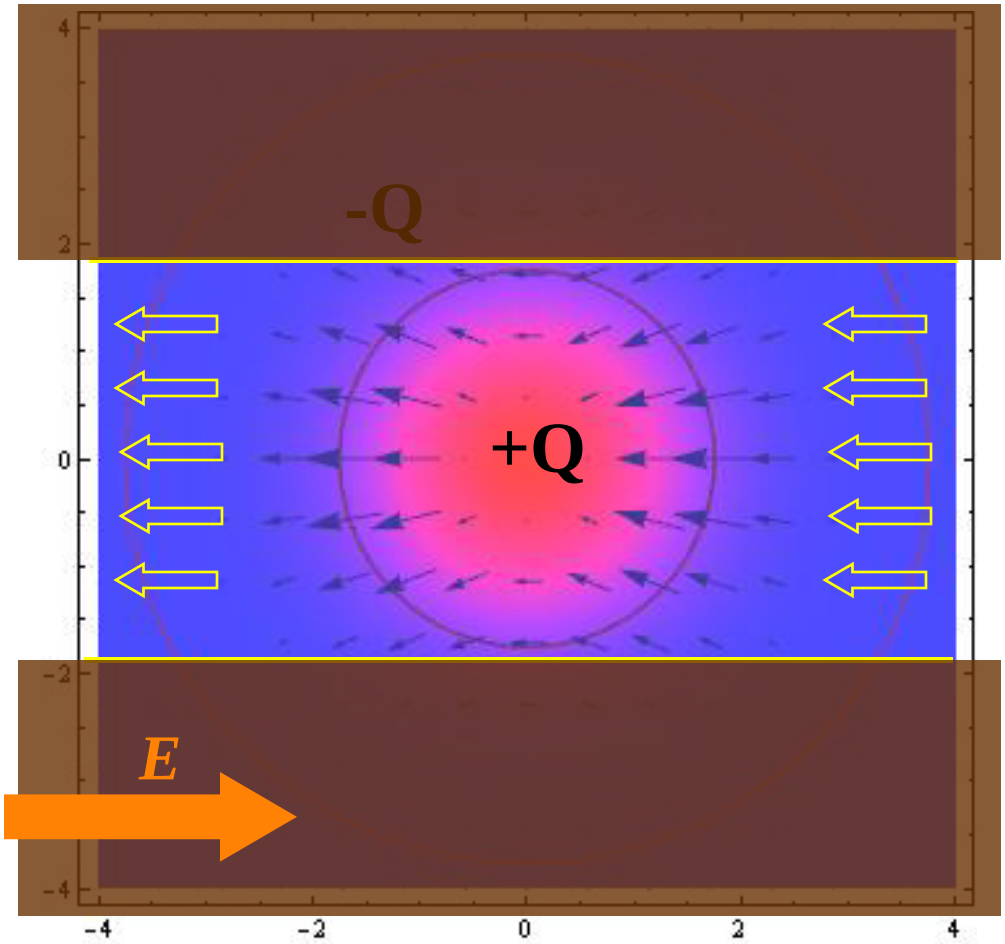

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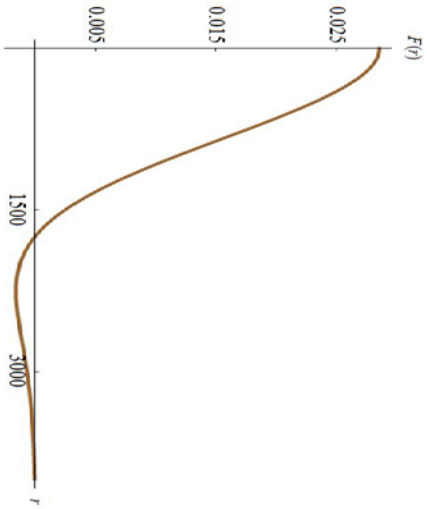

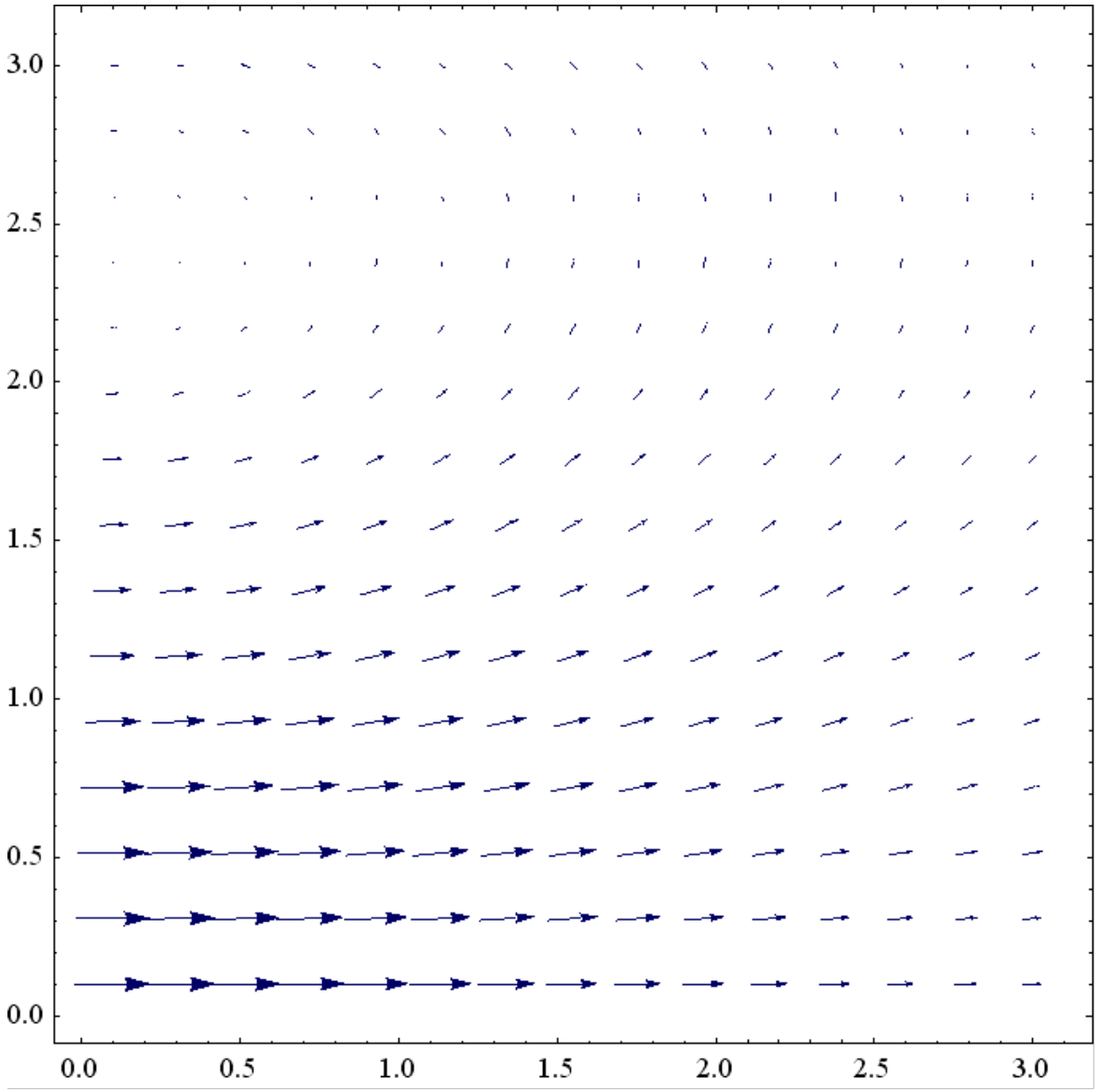
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
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1.0
1.5
2.0
2.5
3.0

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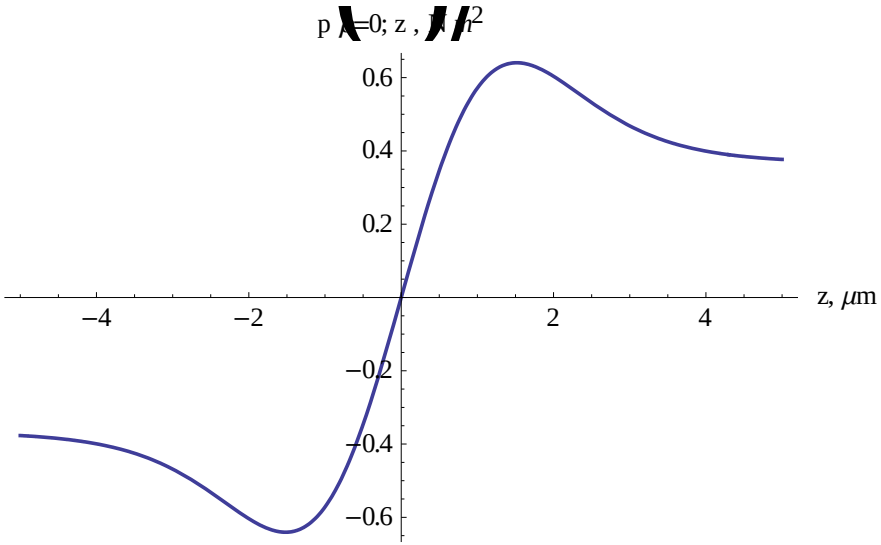

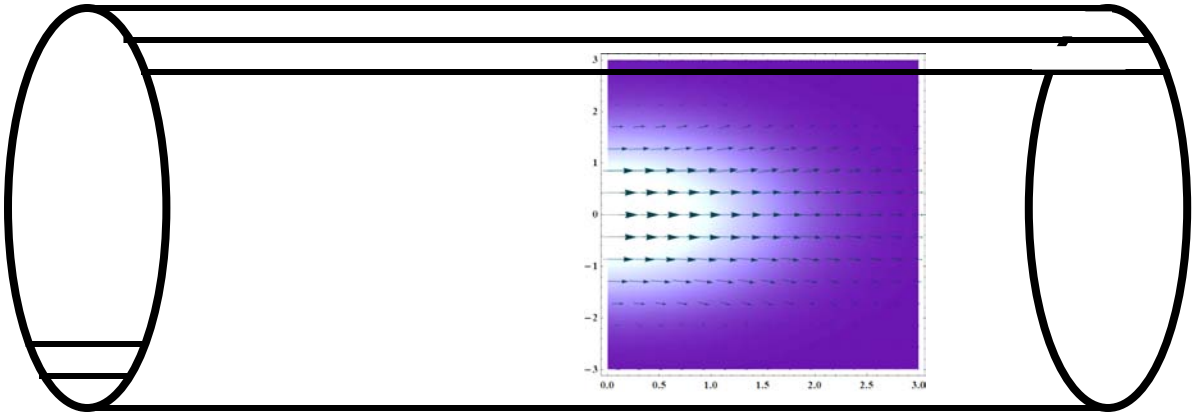

This is Still an Immature Suggestion:

I – The thermal field may help us to construct artificial charged spots inside fluid

II – An electric field then, will cause fluid motion. This can be a good candidate for artificial pumps.

III - Can we borrow the idea of Kirchhoff laws for electric circuits and use them for our, supposed, fluidic networks?

IV – Thank you all, for your attention!