Anistropic media in industrial applications

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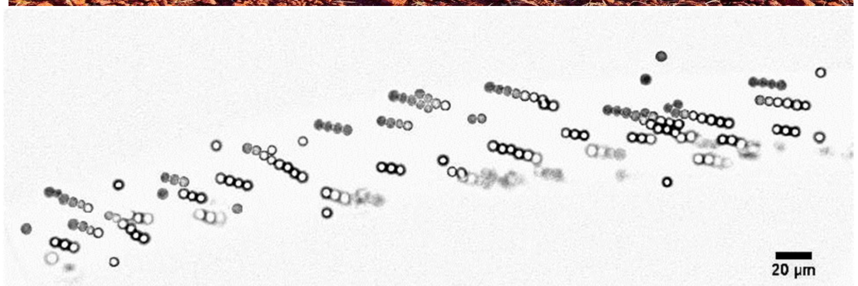

THE ROYAL SOCIETY

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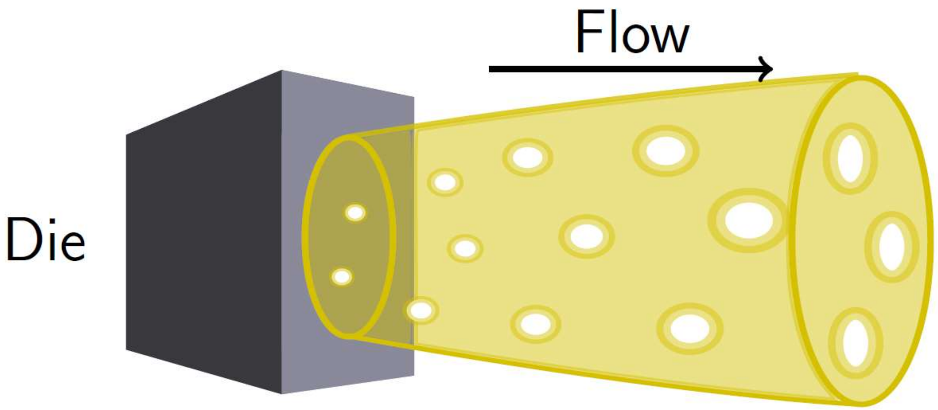
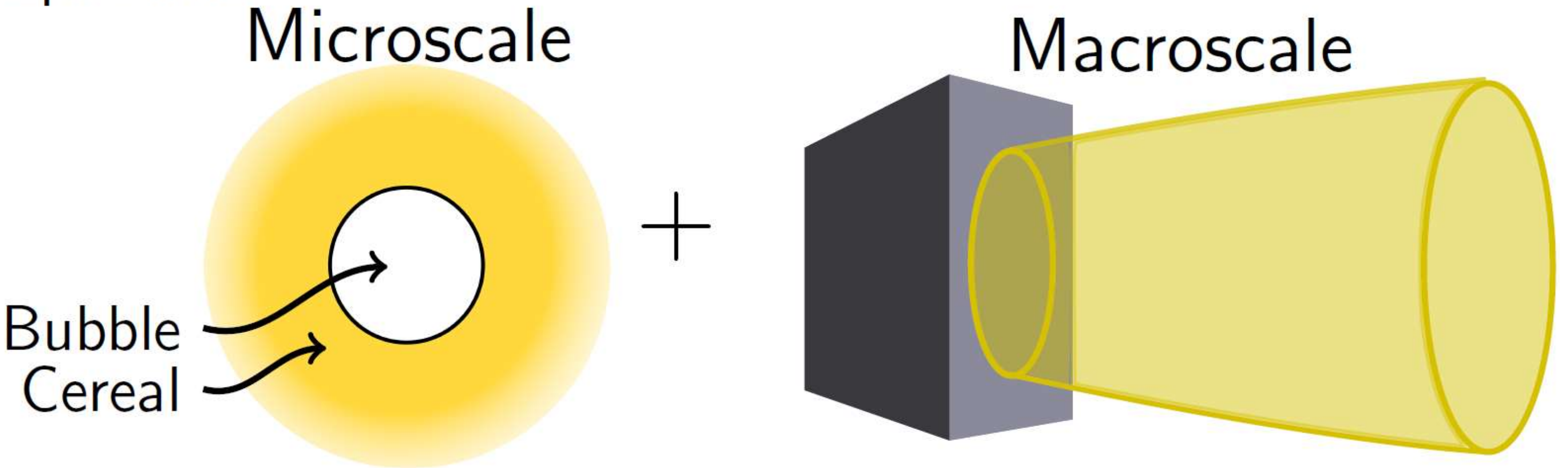
Food science

Food science



Split into:



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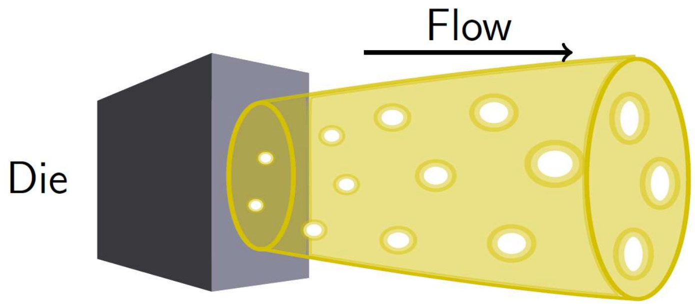
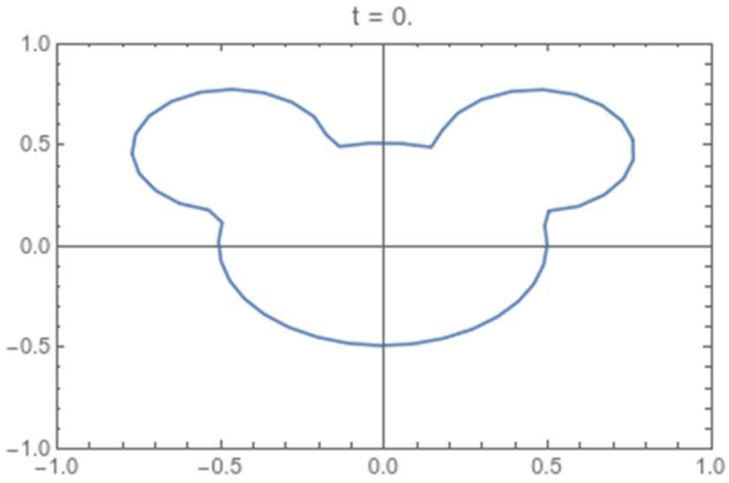
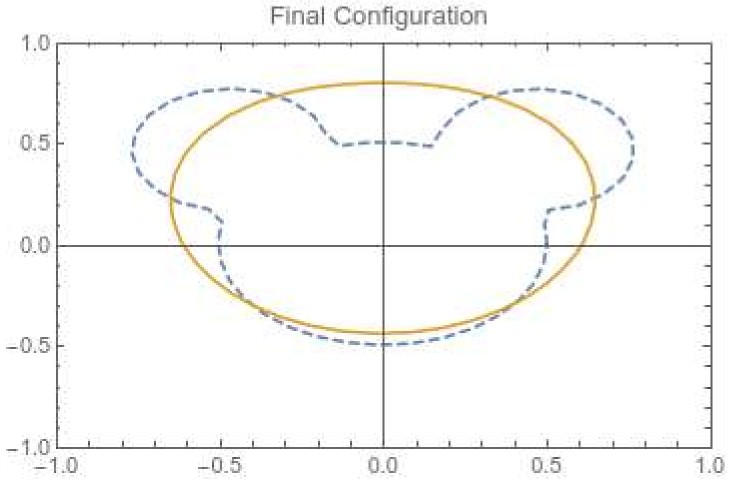
- We have anisotropies in the axial direction and in the cross-plane direction.



- The cross-flow problem can be transformed into a version of 2D Stokes flow.





Food science

- This couples to an axial-flow problem akin to fibre drawing (the Trouton model) for the density ρ, velocity u, and width of extrudate h:

$$\rho u h = Q \qquad \rho u^2 = M \qquad \frac{\mathrm{d}\rho}{\mathrm{d}x} = -\frac{3(1-\rho)\rho\Delta p}{4M^{1/2}(4+3(1-\rho)(\lambda+\mu))}$$

Food science

- Finally, we solve the microscale problem for the bubble evolution.

- This is vital for controlling mouth-feel.

Can you taste a singularity?

- One funded **research project**
- Insight into creation of new **exotically shaped cereals** with **improved taste**

Food science

Shark NINJA

How can we make the perfect smoothie?

- Smoluchowski fragmentation theory captures the chopping process:

$$\frac{dY_i(t)}{dt} = -F(i)Y_i(t) + \sum_{q=i+1}^{\infty} F(q)Y_q(t)\frac{2}{q-1}$$

Concentration of particle size *i*

Likelihood of chopping a piece of size *i*

There are q-1 ways of chopping a piece of size q, and two of these ways make a piece of size i

Food science

Shark|NINJA

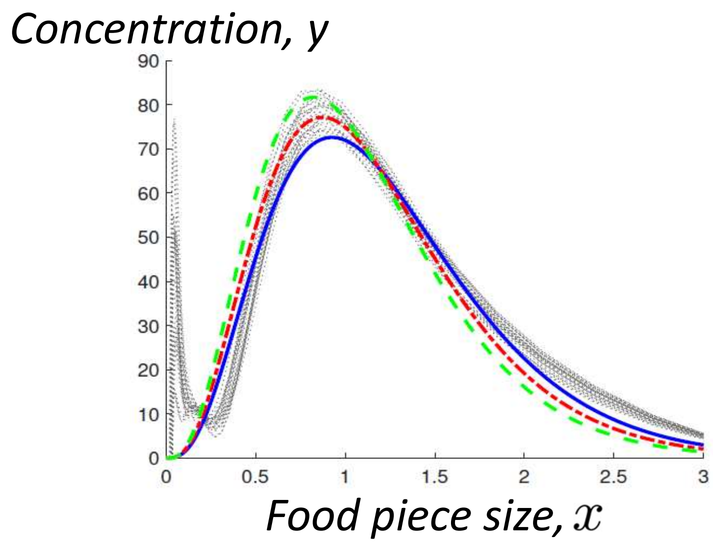
- In practice we have a continuum of particle sizes:

$$\frac{\partial y(x,t)}{\partial t} = -f(x)y(x,t) + \int_x^\infty f(s)y(s,t)\frac{2}{s}\,\mathrm{d}s$$

- Similarity solutions match well to experiments.

$$f(x) = x^k$$

Concentration, $y = \dfrac{kt^{2/k}\mathrm{e}^{-x^k t}}{\Gamma\left(\frac{2}{k}\right)}$



Food science

- One funded **research project**
- One cross-disciplinary **journal article**
- **Implementation** of a new blade for NutriNinja blenders

unicef

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Bangladesh

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Providing safe water for families in Bangladesh

By Naimul Haq

BAGERHAT DISTRICT, Bangladesh, 24 February 2010 — Defying stifling heat and humidity, Maya Begum walks more than an hour from her village to fill two large plastic containers with drinking water for her family of four.

The INDEPENDENT

Arsenic-tainted water from Unicef wells is poisoning half of Bangladesh

PETER POPHAM IN DHAKA | Saturday 05 September 1998

Karagas, The Lancet, 2010

A strategy for arsenic removal?

- Iron-rich laterite soil removes arsenic.

- How do we know when a filter has expired?
- How do we upscale for a school or community?

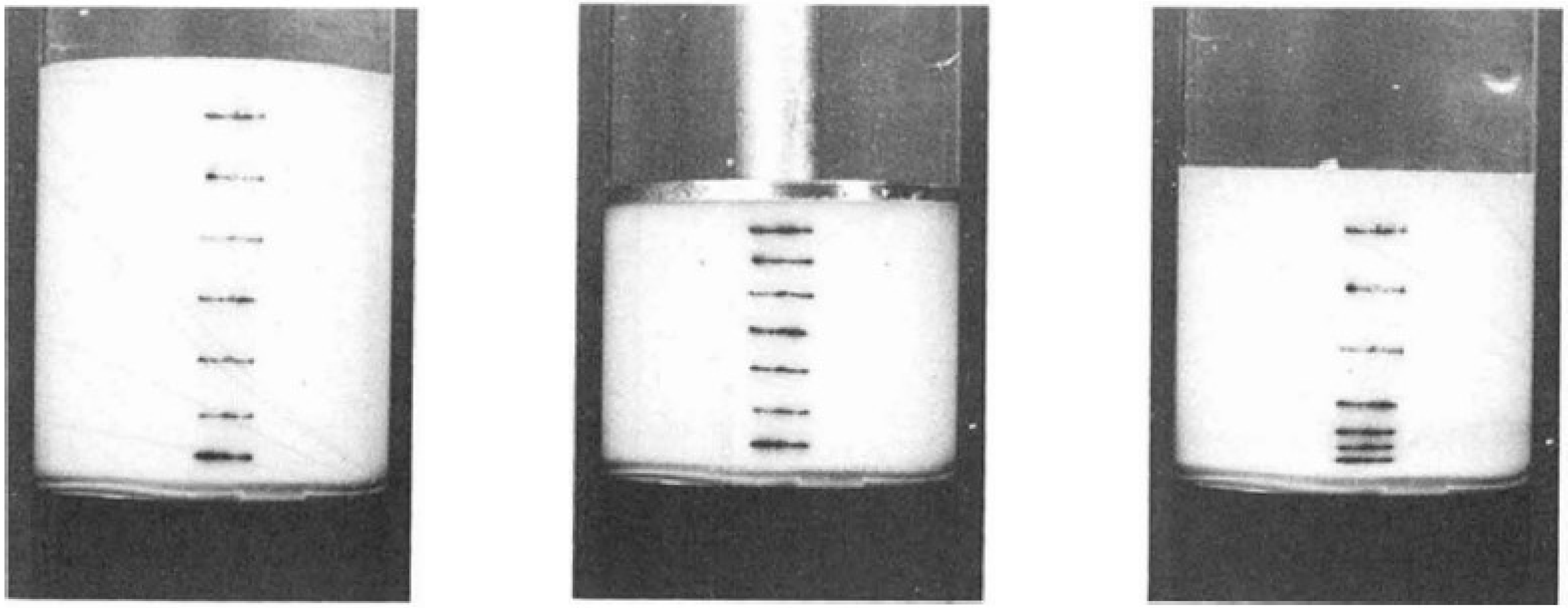
State of deployment

- **Three-year collaboration** with **IIT Kharagpur**
- Filters in **5000 family homes**
- **UNICEF** have commissioned **40 community-scale filters**
- Now studying **fluoride** and **reactive dye removal**

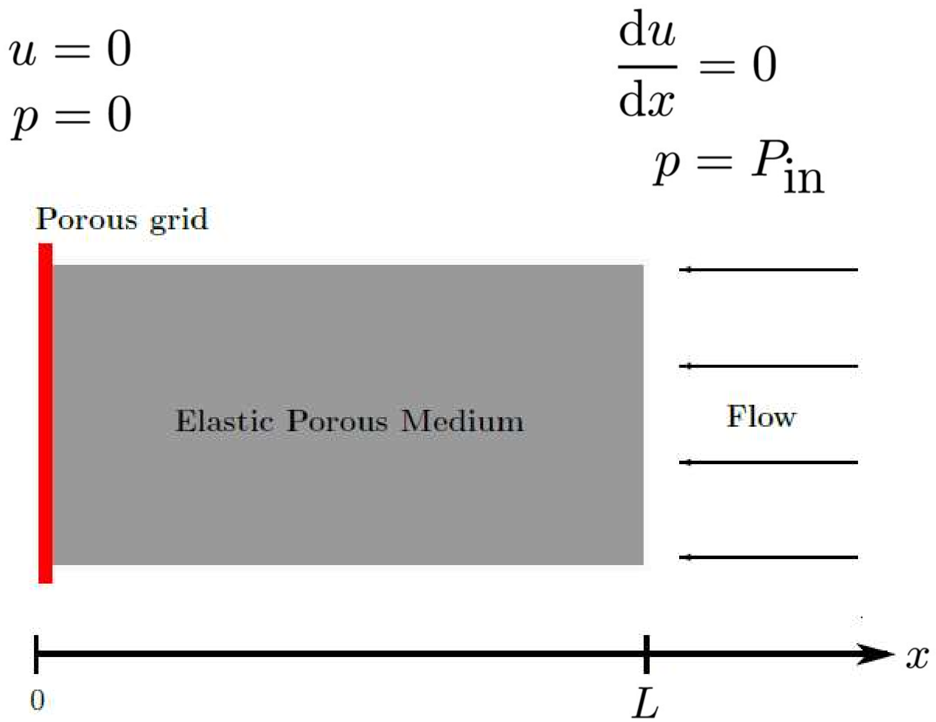
Ambika Soudamini school 1500 litres per day

Dutta Pukur 2000 litres per hour

Compressible filters



Compressible filters

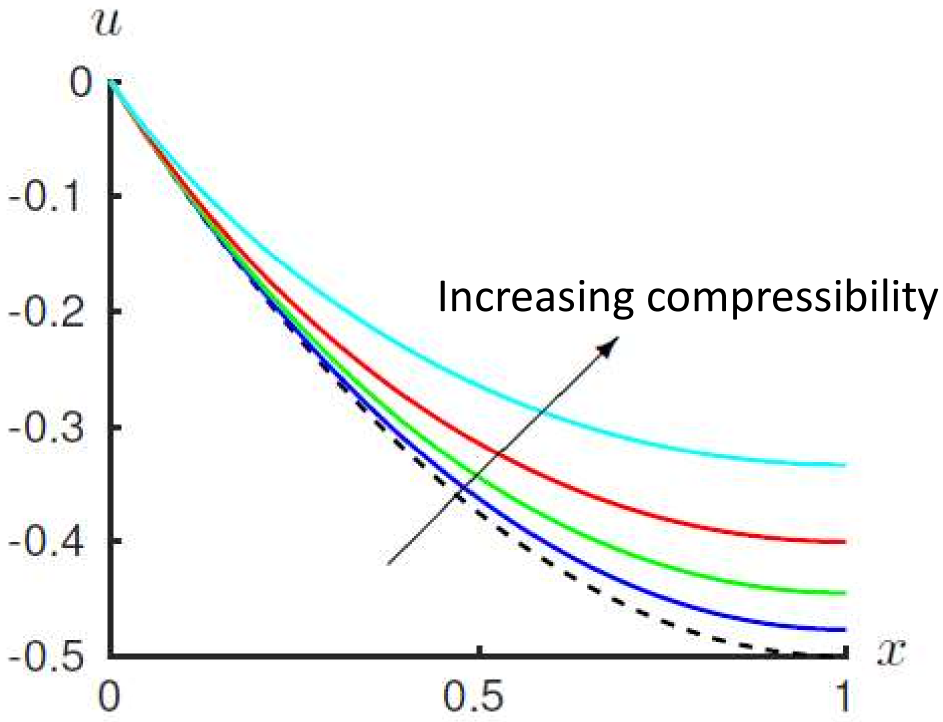


$$(\lambda + 2\mu)\frac{\mathrm{d}^2 u}{\mathrm{d}x^2} = \frac{\mathrm{d}p}{\mathrm{d}x}$$

$$q = \frac{k}{\eta}\frac{\mathrm{d}p}{\mathrm{d}x} = \text{constant}$$

$$k = k_1 + k_2\frac{\mathrm{d}u}{\mathrm{d}x}$$

Compressible filters



- The filter compressibility leads to shutdown of the membrane.

- We can choose an initial permeability distribution *k* that leads to a uniform permeability under operation.

This work can give insight into improving and optimizing the filtration process

Liquid crystal microfluidics

- The opportunity to merge liquid crystals and microfluidics in liquid crystal microfluidic devices has shown promise in enhanced particle control and manipulation:

Liquid crystal microfluidics

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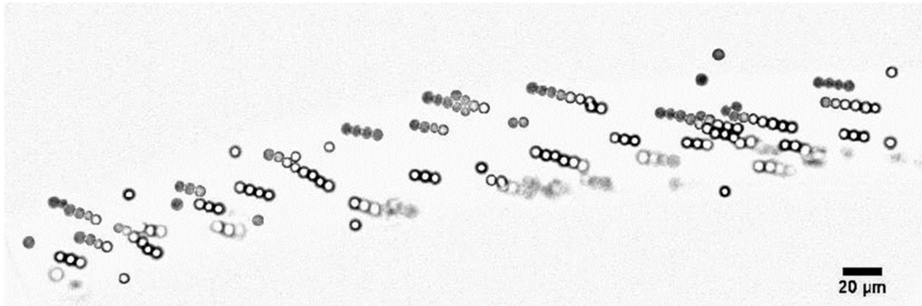
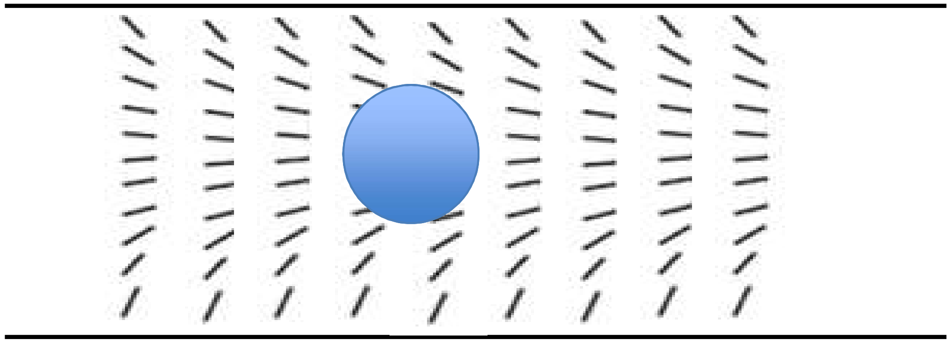


- Interesting flow dynamics are observed experimentally depending on the strength of the flow field.

Liquid crystal microfluidics



- When we add particles to the flow they distort the liquid crystal molecules.
- We must solve for the liquid crystal orientation (Beris–Edwards) and the flow field (Navier–Stokes).
- Both the flow and the liquid crystal molecules exert a force on the particle:

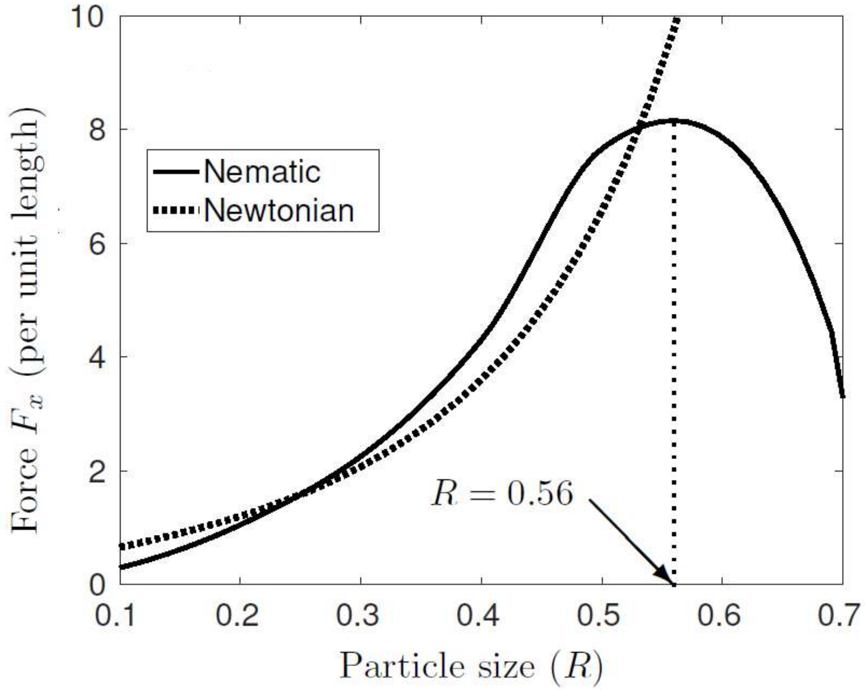
$$\mathbf{F} = -\int_{\omega} \left[\mu\left(\nabla\mathbf{u} + (\nabla\mathbf{u})^{T}\right) - p + \boldsymbol{\sigma}\right] \cdot \mathbf{n} \, \mathrm{d}\omega$$

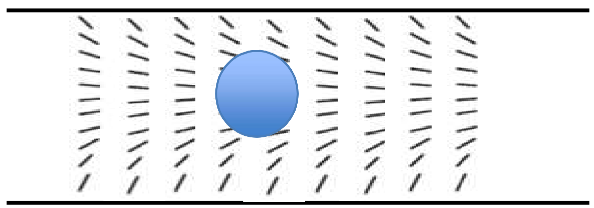
viscosity
velocity
pressure
stress tensor
normal

The drag on a particle

- Newtonian fluid: drag increases monotonically with particle size (viscous drag).

- Nematic liquid crystal: a maximum drag exists (as the particle size increases and its edges become closer to the walls and anchoring effects will hold the particle back).

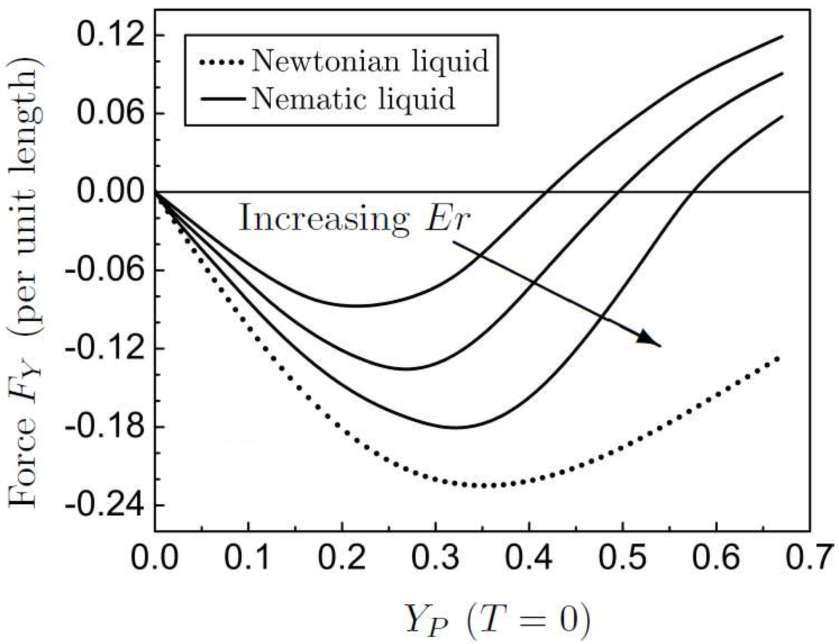


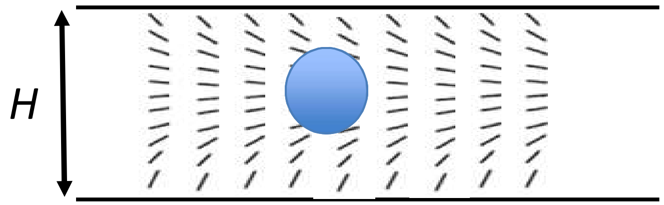


The lift on a particle

- Newtonian fluid: particles always move to the centre of the channel.

- Nematic liquid crystal: particle may move to centre or to the wall depending on start location.





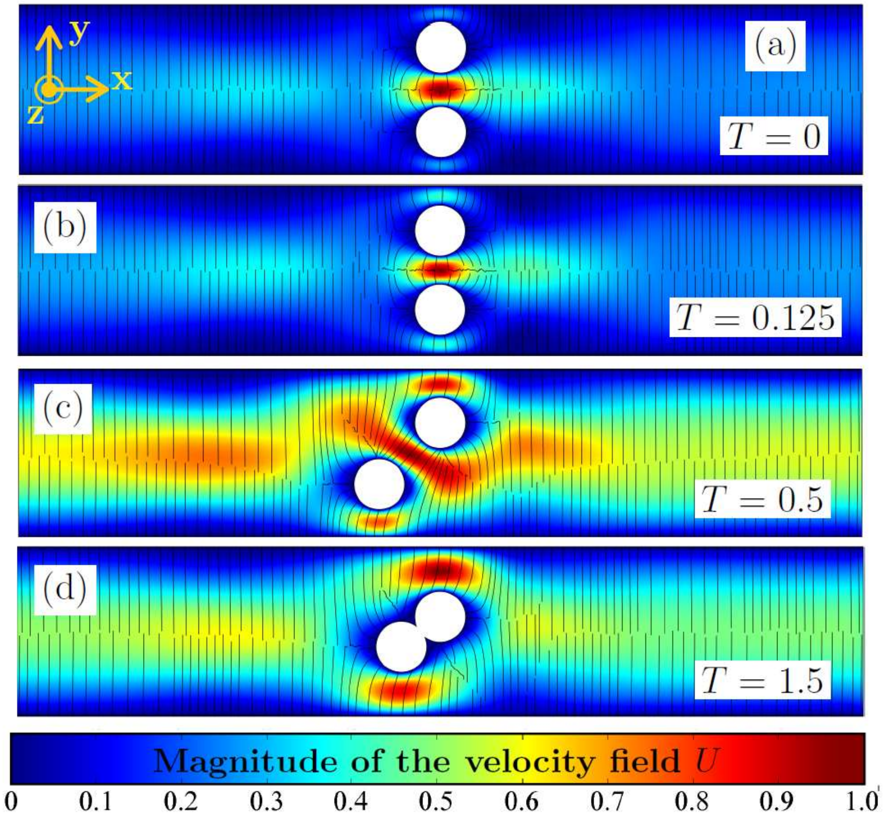
$$Er = \frac{\mu H U}{\alpha}$$

- This provides a possible mechanism for particle sorting.

Two particles

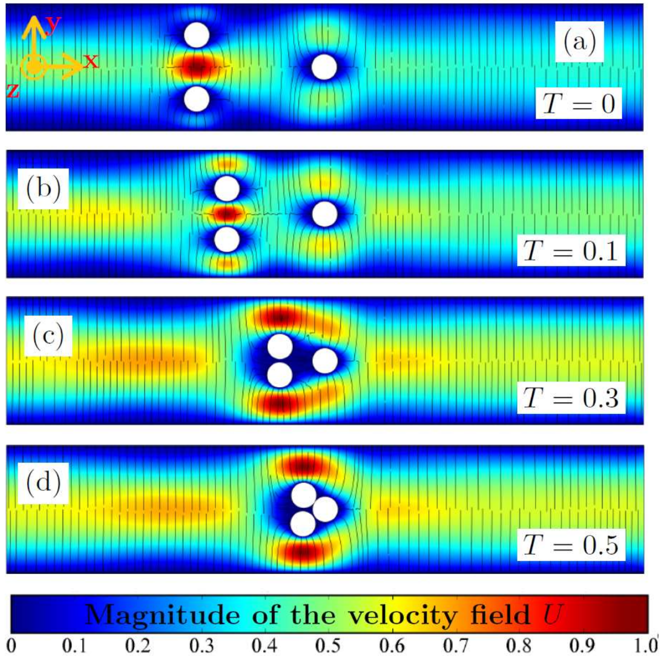
- If we place two separate particles into an NLC flow then they will aggregate.

- They equilibrate at an angle of approximately 41° to the flow direction

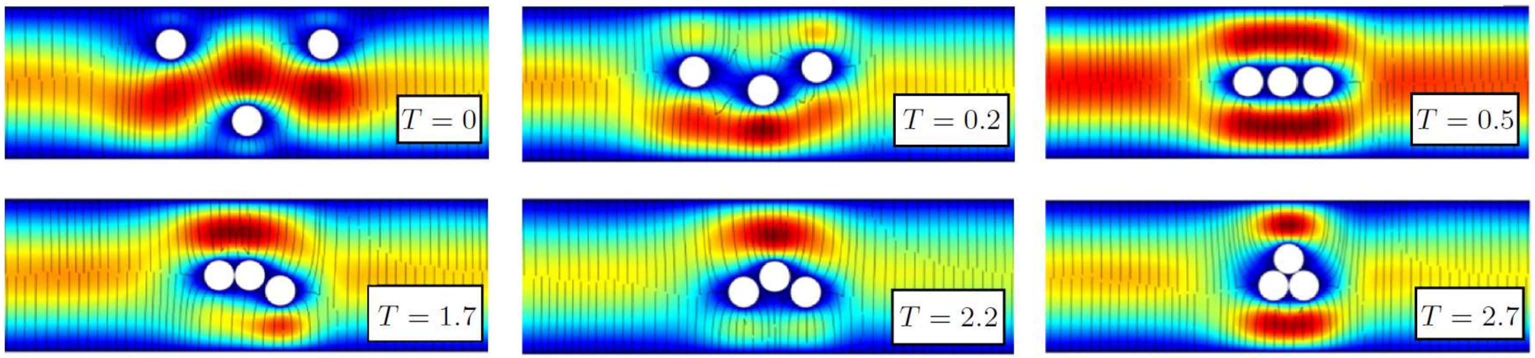


Three particles

- Three particles placed in a flow will also aggregate.



- The initial configuration matters:



We are now using our work to understand how **image sticking** occurs in LCD devices

Conclusions and outlook