Modelling Magnetics for Better Control in Microfluidic Cell

Shriya Haravu

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Introduction

What is the ASAP project?

The goal of the ASAP (Actuating Surface Attached Posts) project is to create a lab on a chip capable of moving fluid, directing flow, and capturing cells. This experimental setup mimics that of cilia in our lungs and is comprised of a microfluidic channel filled with micron sized posts. The post arrays (which can take various geometries) are made of PDMS and actuated with magnets in order to create directed flow. There are two aspects of the ASAP project. One involves trying to quantify and understand what is happening inside the microfluidic channels. The other involves controlling what happens inside the microfluidic channels. The magnetics modelling is related to the latter.

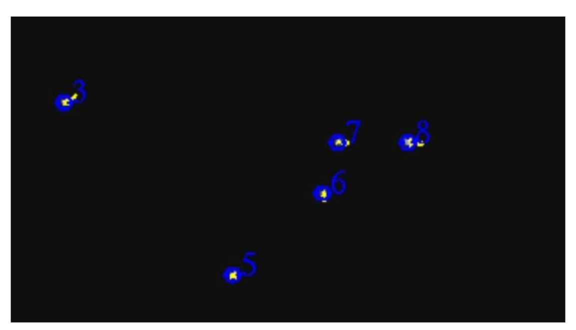
Why is magnetic actuation important?

Creating directed fluid flow and mixing fluids at the micro-scale is very difficult because of the low Reynolds number environment. Passive mixers, like stationary obstacles inside a fluid cell, are not as effective as active mixers. The arrays of cilia-like posts pictured here are made out of a plastic known as PDMS, are micron-sized, and are filled with magnetic nanoparticles at the tips such that they can be magnetically actuated and function as active drivers of fluid movement. Magnetic actuation of the posts with current carrying wires as opposed to permanent magnets can allow for more precise control of individual post movements. But, the field strength needed to actuate the posts is much higher than that which can be achieved by a current carrying wire alone. We are exploring how/whether a magnetic coating surrounding a wire placed alongside the post array could significantly amplify the field strength enough to affect the actuation of posts.

- **Reynolds number** – ease with which fluid can be displaced
- Low vs High: Laminar Smooth Flow vs Turbulent Flow

  - Velocity of fluid
  - Viscosity of fluid
  - Density of fluid
  - Temperature
  - Characteristic length

$$\mathrm{Re} = \frac{\rho u l}{\mu} = \frac{ul}{\nu} = \frac{F_{inertial}}{F_{viscous}}$$



Bead flow through a microfluidic channel can be tracked using Video Spot Tracker Software. Here the paths of the fluorescent beads are being tracked by the blue markers.

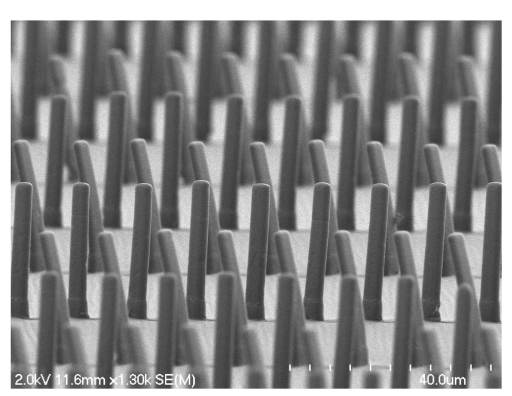
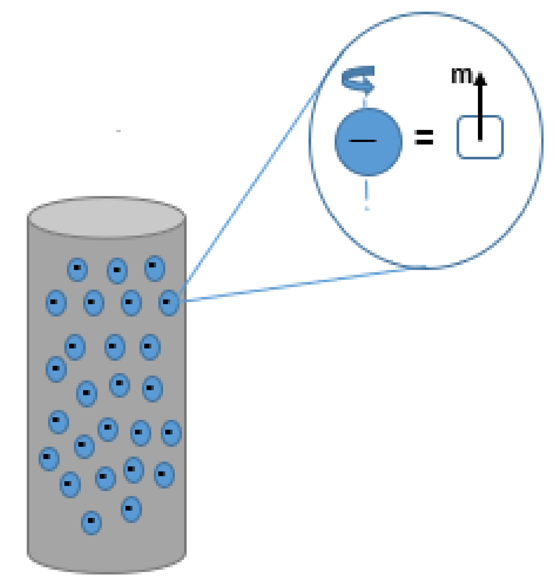


Image taken by Jacob Brooks of one of the post arrays he fabricated. SEM (Scanning Electron Microscope) Image

Magnetics



m= dipole moment

M= dipole moment/unit volume = Magnetization

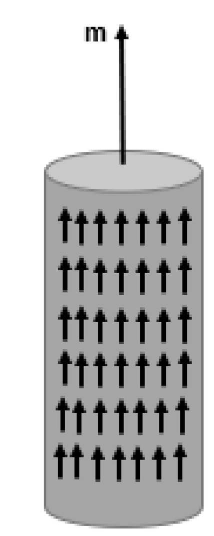
B= Magnetic Field

I = Current

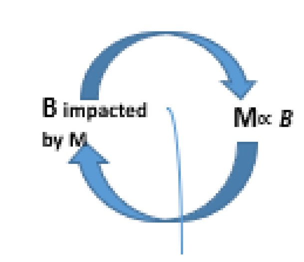
r = radial distance from the cylinder's central axis

a = radius of the cylinder

L= length of the cylinder

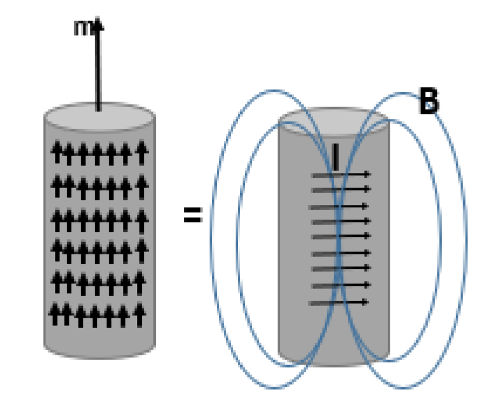


Uniformly magnetized permanent magnet. The dipole moment can contribute to a magnetic field.



H = (B/u0)-M

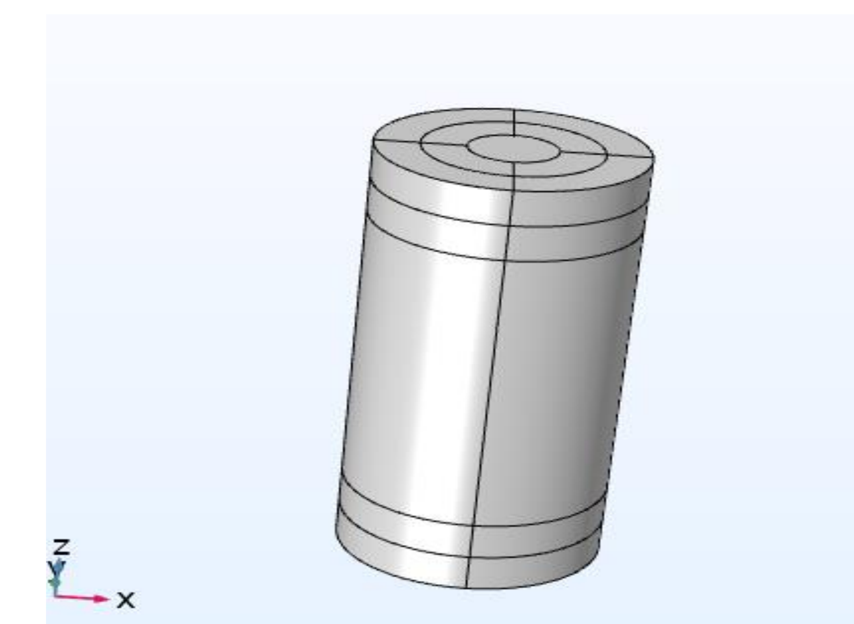
H, a quantity which can be fully characterized by enclosed current, allows us to ignore the circular logic between B and M. It's the quantity used to solve for the magnetic field B inside and outside of a cylindrical magnet as a function of magnetization M. How?



Uniform volume magnetization can be interpreted in terms of a bound surface current. (I)

∫ H• dl = Ienclosed

Magnetic Field Inside Magnet	Magnetic Field Outside Magnet
$u_0M(1+L+r)$	$u_0M(2\pi aL + 2\pi a^2)/2\pi r$

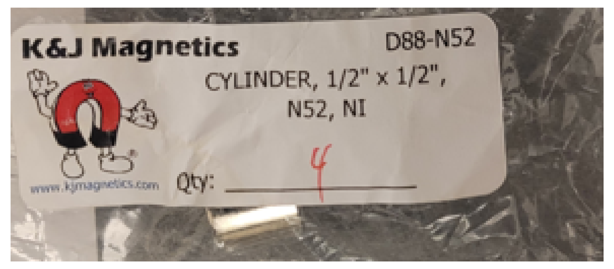


Cylindrical geometry built in COMSOL's Magnetic Fields No Currents Interface

Gauss Meter Measurements for Cylindrical Permanent Magnets (Magnetized on Axis):

Magnet 1: .5" x .5", N52, NI D88-N52	Magnet 2: .5" x 1", N42, NI D8X0
˜5400 Gauss close to surface	˜5400 Gauss close to surface
˜1000 Gauss ½ inch above surface	˜600 Gauss ½ inch above surface
˜100 Gauss 1 inch above surface Analytical soln. returns: 56.34 G	˜100 Gauss 1 inch above surface Analytical soln. returns: 83.82 G

Repetitions of measurements will be taken to increase accuracy



Method:

The immediate goal is to use COMSOL to model the magnetic field drop off from a current carrying wire coated in magnetic material. To ensure that it is built correctly we use analytical solutions, lab measurements, and the COMSOL model to validate each other and will do so until reaching a point where the COMSOL model is the only source from which we can extract information. The steps involve first modelling a cylindrical block magnet with specific magnetization in COMSOL, then adding a uniform magnetic field representing the presence of an infinitely long current carrying wire, and then modelling specifically a current carrying wire coated in magnetic material. Pictured here is a diagram showing how the analytical solution and Gauss meter measurements are being used while modelling a cylindrical block with specific magnetization in COMSOL (in progress).

Acknowledgements: **Richard Superfine, Michael Falvo, Jacob Brooks, Viviana Calderon, Jeremy Cribb, & all Lab Members**