SIGGRAPH ASIA 2020 VIRTUAL

Pre-recorded sessions:
From 4 December 2020

Live sessions:
10 – 13 December 2020

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Surface Only Ferrofluids

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Overview

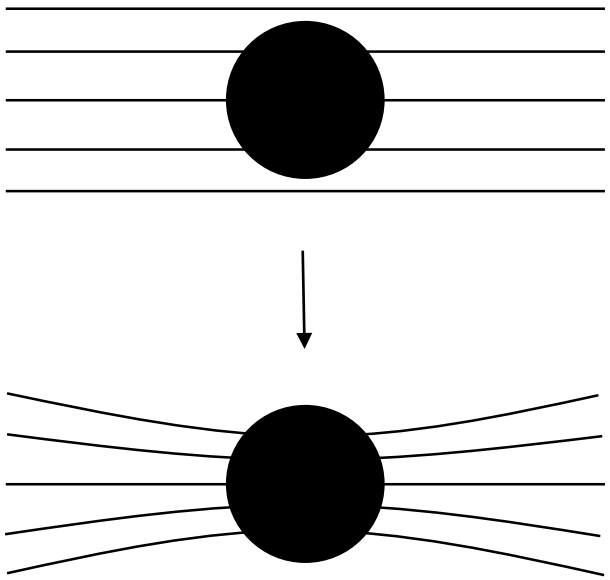
- Introduction (10%)
- Related Ferrofluid Simulation (10%)
- Surface Only Liquids (20%)
- Make It Magnetic! (30%)
- Results (25%)
- Conclusion (5%)

Introduction: What?

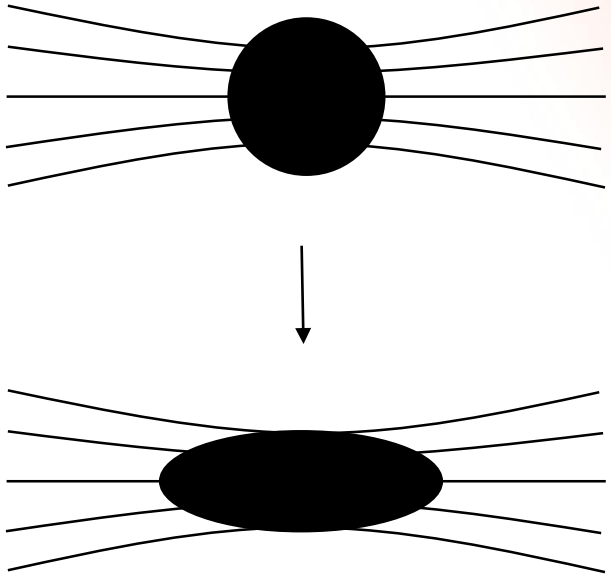
- Ferrofluid: magnetic fluid
- Spikes: minima of
  - Surface tension
  - Gravity energy
  - Magnetic energy

Introduction: How?

- How to solve magnetic fields?

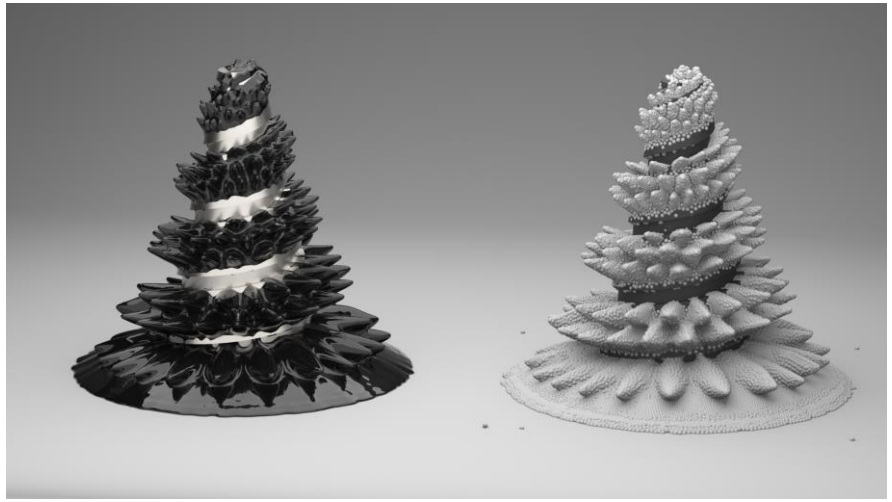


- How to apply magnetic forces?



Related Ferrofluid Simulation

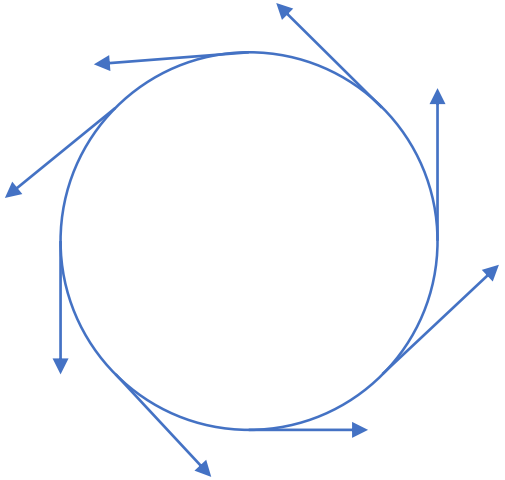
- Huang et al. 2019
  - Radial basis functions
  - Inter-particle forces
  - Surface tension?

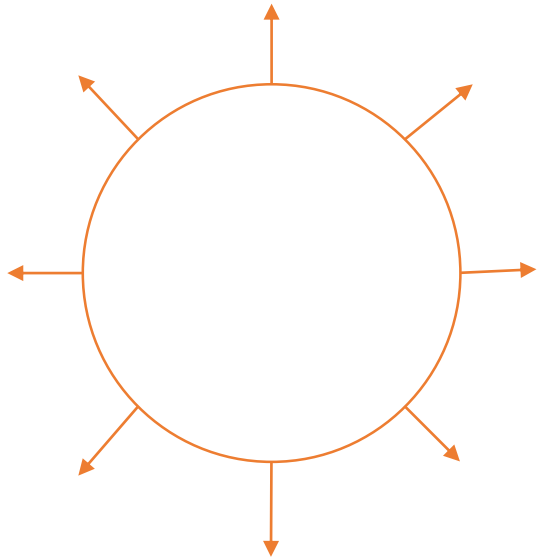


- Ni et al. 2020
  - Cartesian grids
  - Pressure boundary condition
  - Extra air DOF?

Surface Only Liquids

- Origin: Da et al. 2016 “Surface-only Liquids”
- Key assumptions: curl-free and divergence-free





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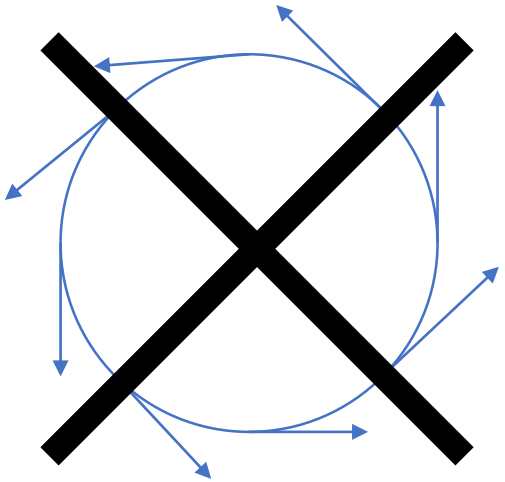
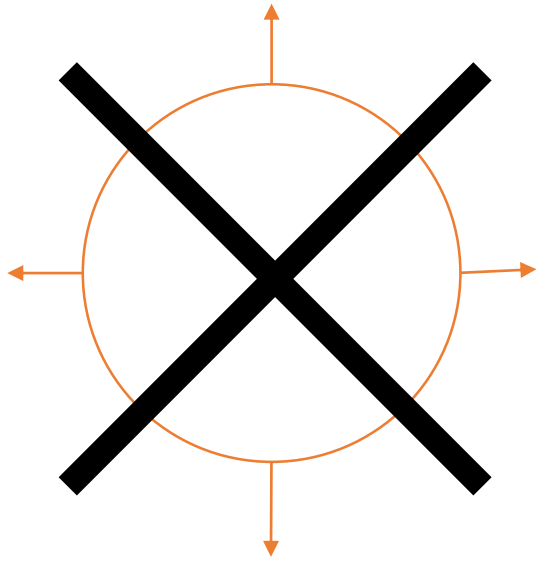
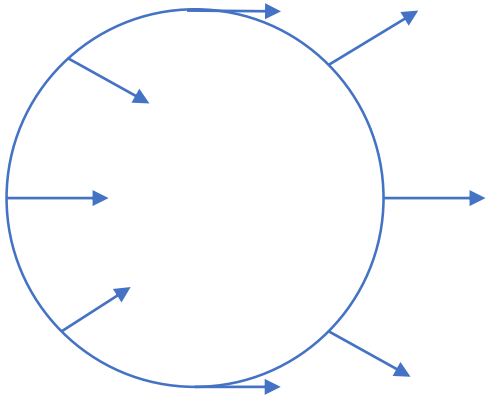
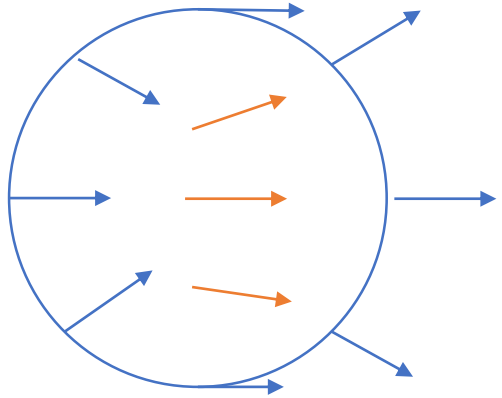




Surface Only Liquids

- Key assumptions: curl-free and divergence free
- The interior velocity is uniquely defined by the boundary velocity.



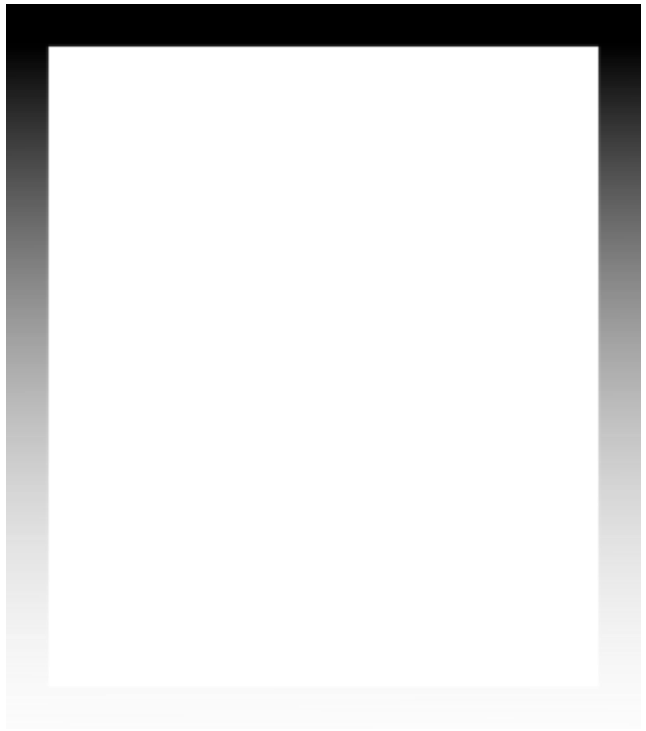


Surface Only Liquids

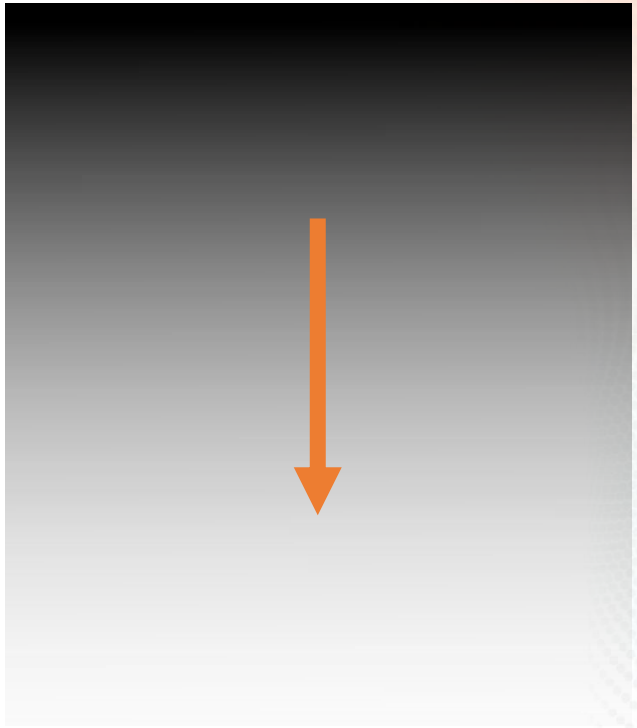
- Main steps:
  1. Move boundaries to new positions
  2. Make new velocity fields harmonic (curl-free and div-free)
  3. Add forces as harmonic vector fields.

Make It Magnetic!

- Basis: add forces as gradient of harmonic function
- Example: gravity (top pressure=0), constant gradient

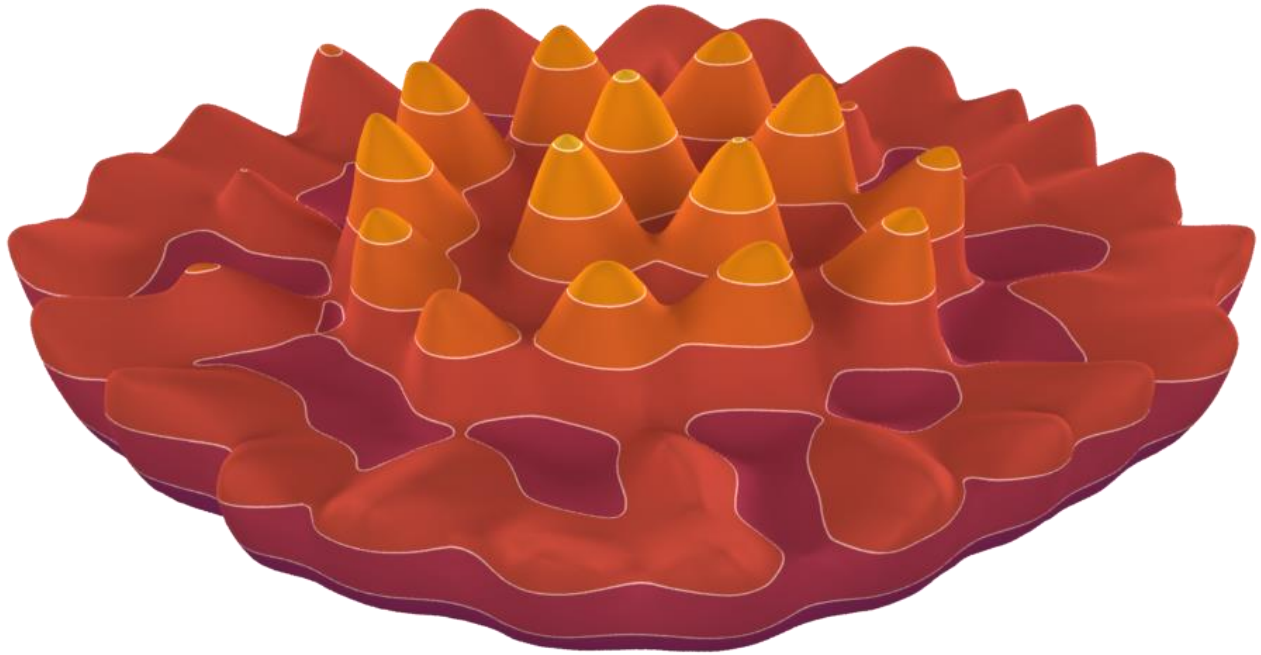


solve boundary value problem->



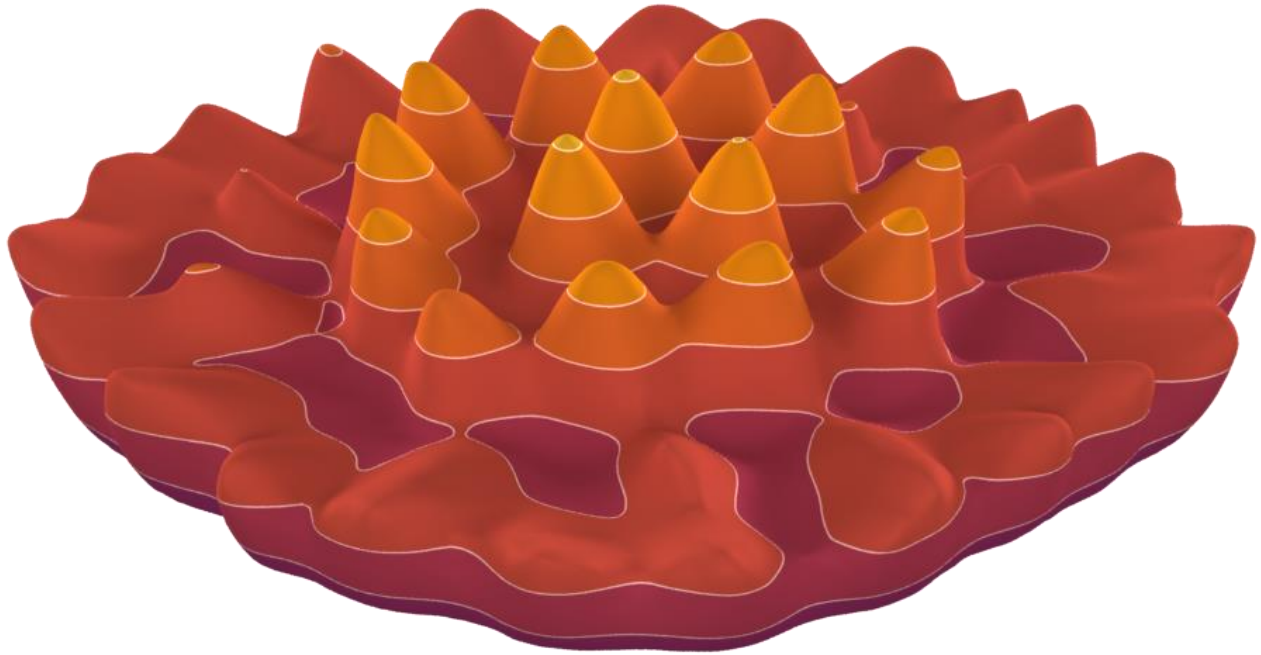
Make It Magnetic!

- Still gravity, but in a real simulation:



Make It Magnetic!

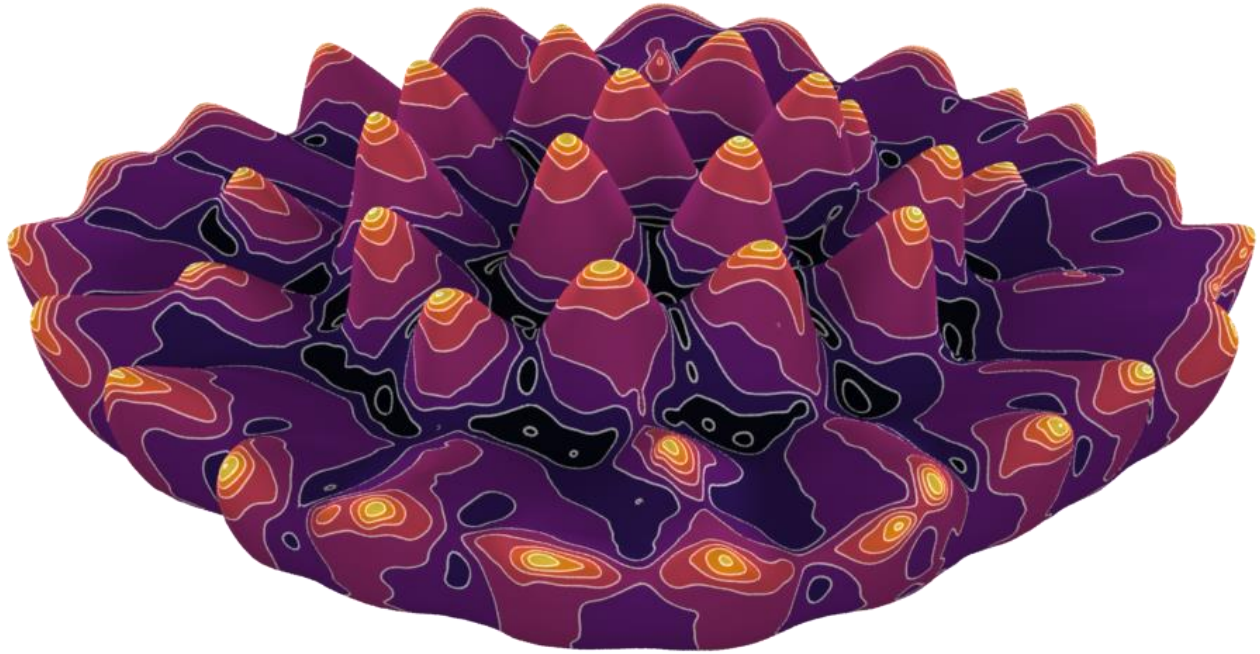
- Gravity energy = negative integral of gravity body forces



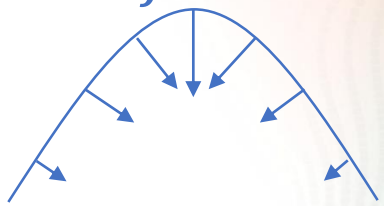
$$f_{gravity} = \rho g$$

Make It Magnetic!

- Surface tension energy = negative integral of surface forces

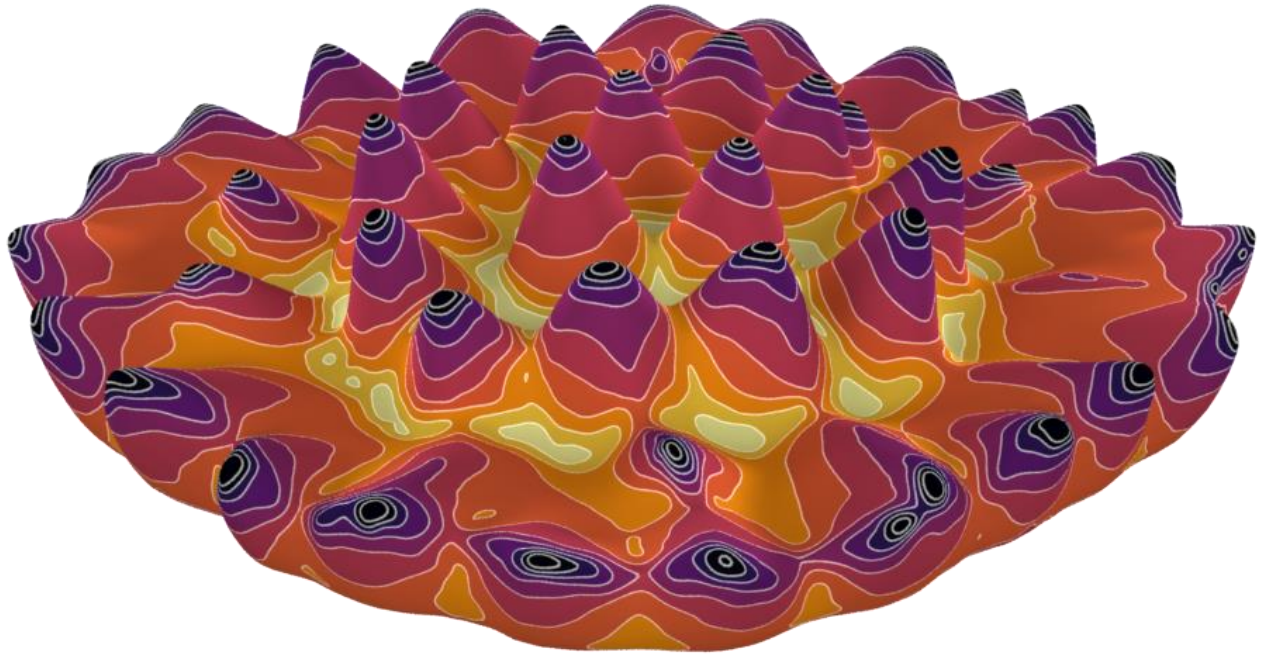


$$f_{surface} = \sigma H$$



Make It Magnetic!

- Magnetic energy = negative integral of magnetic body + surface forces



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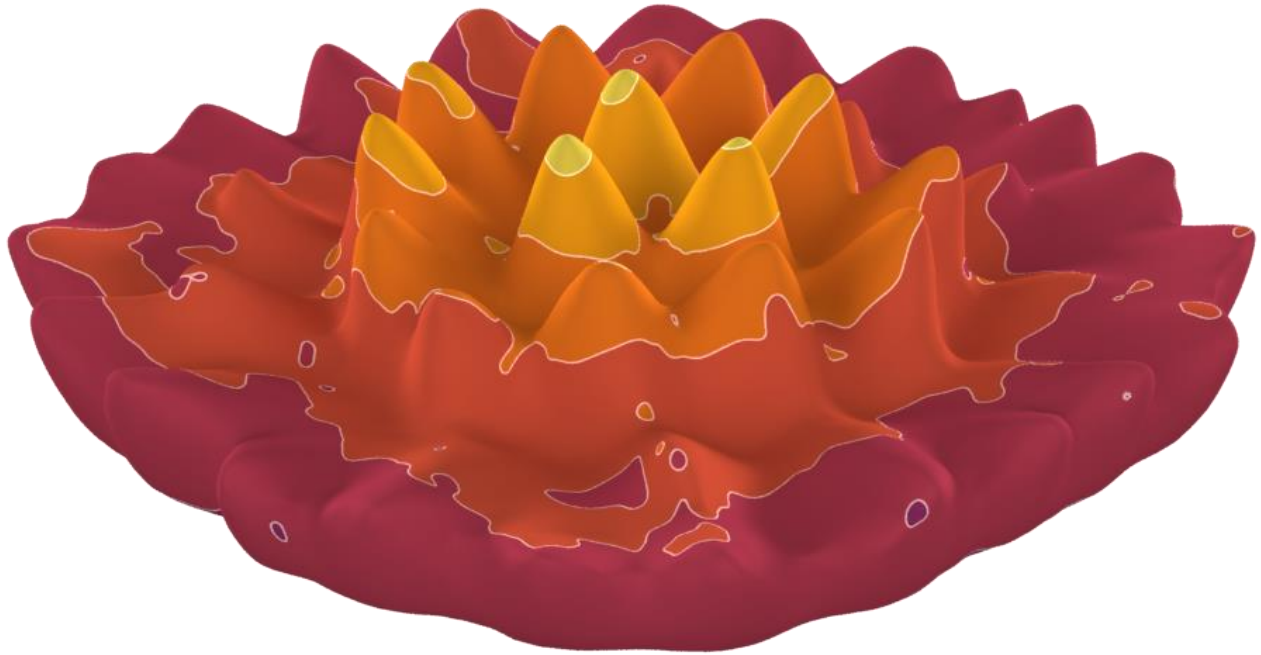
Make It Magnetic!

- $E = E_{Surface} + E_{Gravity} + E_{Magnetic}$



Make It Magnetic!

Put it all together:

1. Solve the magnetic field (BEM)
2. Get magnetic energy on surface
3. Add gravity, surface tension
4. Solve the gradient with BEM
5. Add the gradient to the velocity

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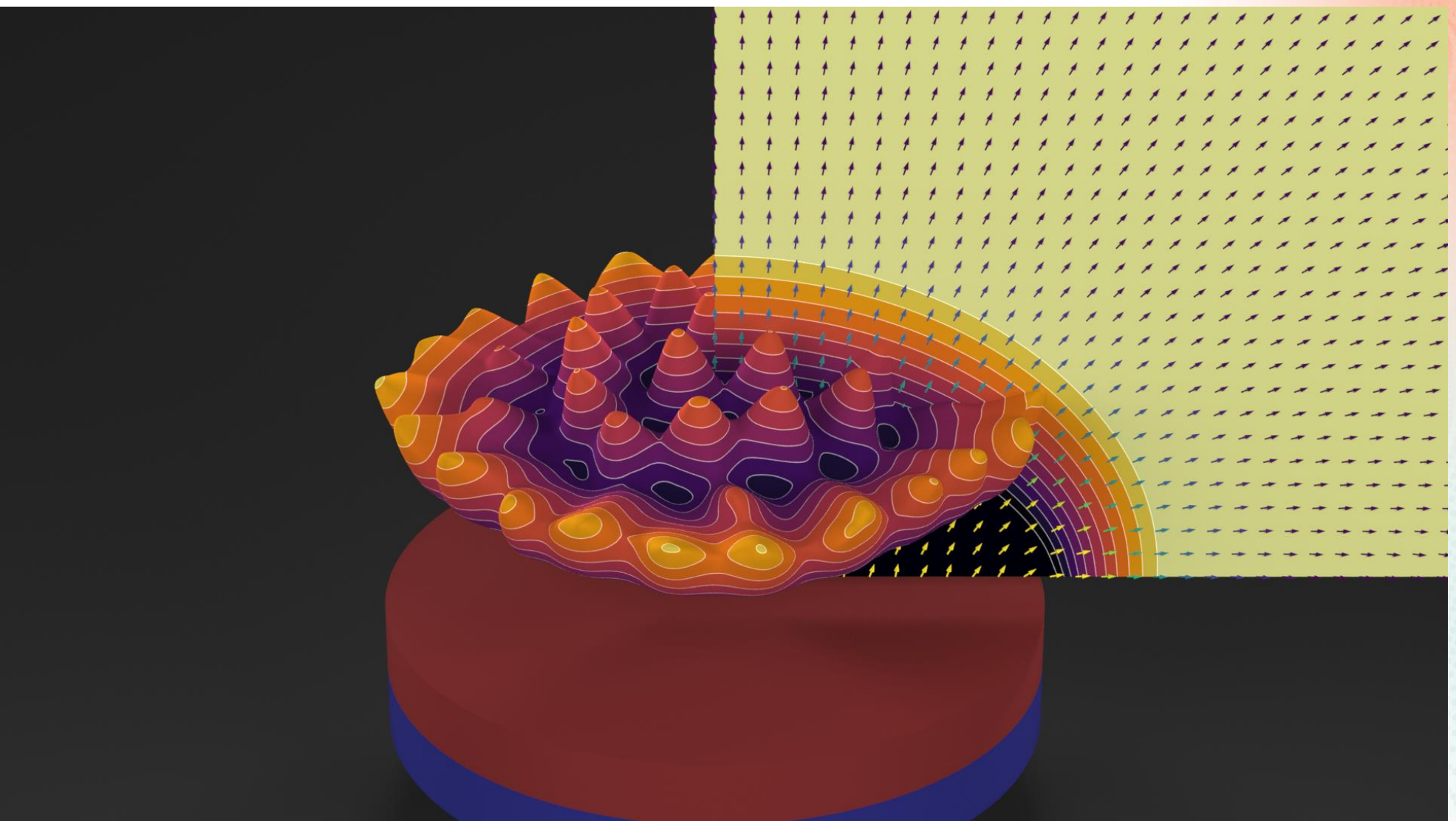
Results



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Results

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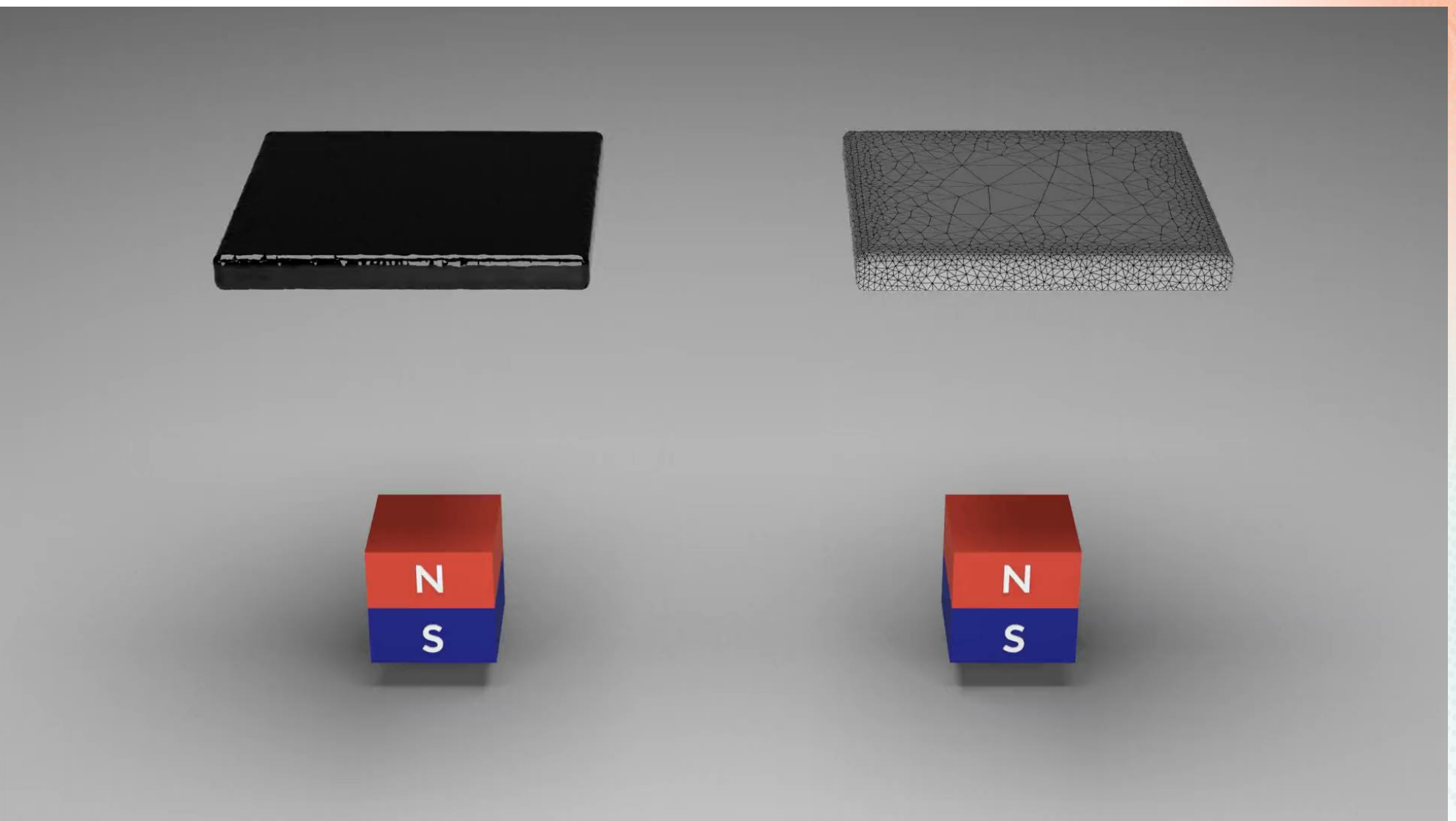

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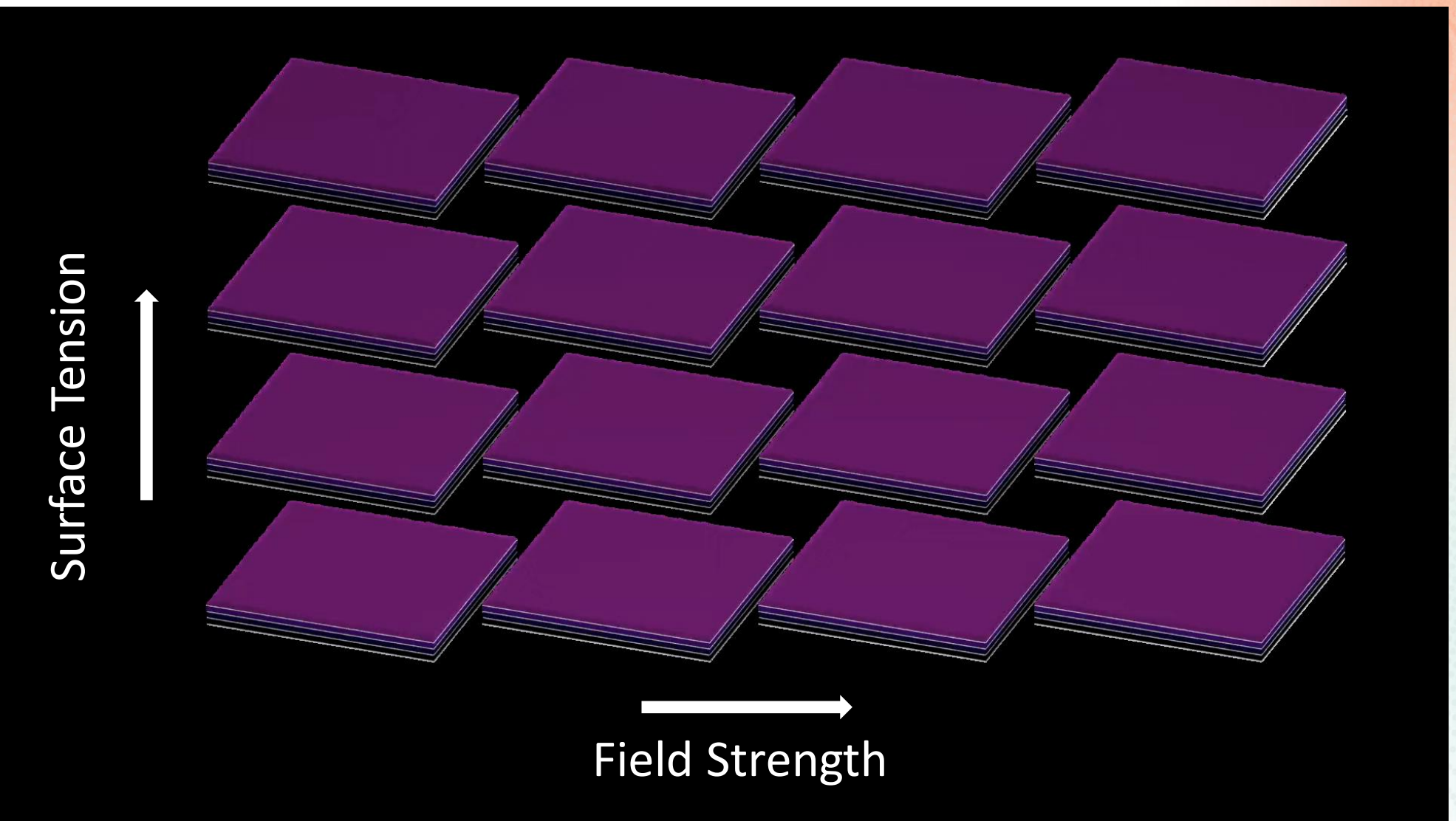
Results



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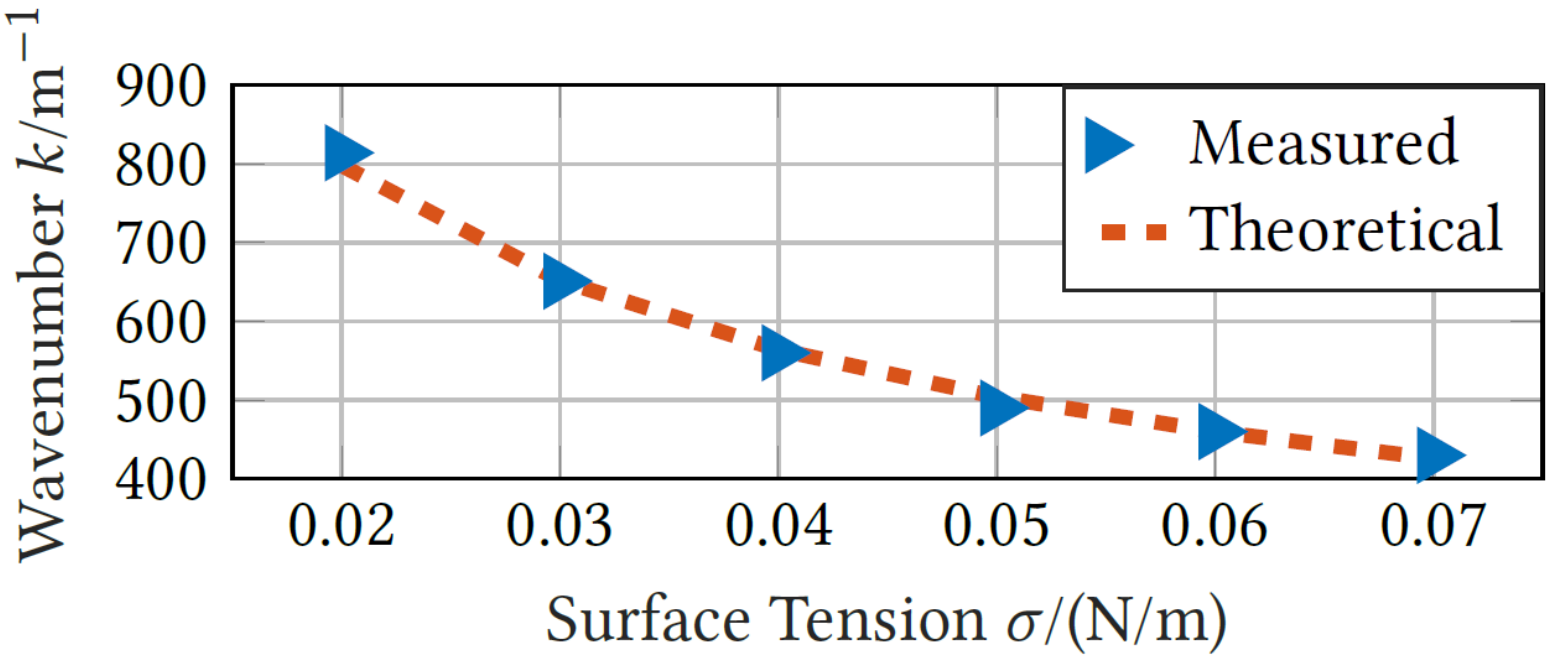
Results



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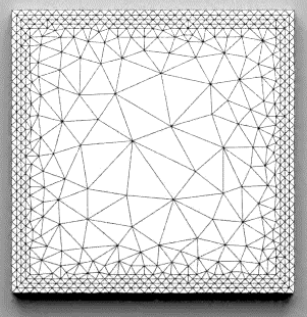
Results



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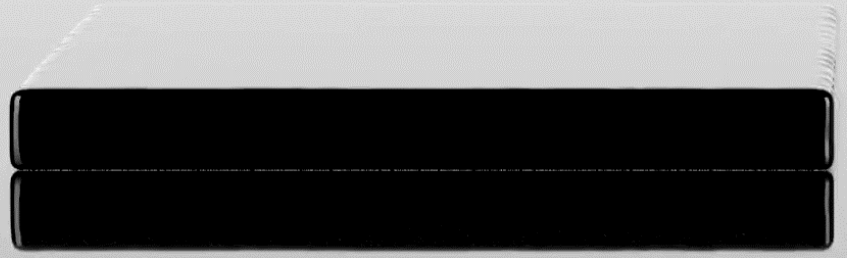
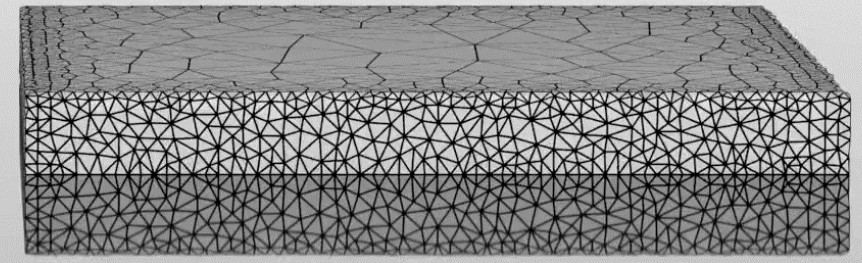
Results





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Conclusion

- Incorporate magnetic effects by adding magnetic energy on the surface using BEM
- Benefits:
  - Less unknowns
  - Accurate surface tension
- Drawbacks:
  - Limited to linear material
  - Complex boundary handling
  - Difficult implementation

KAUST Computational Sciences Group