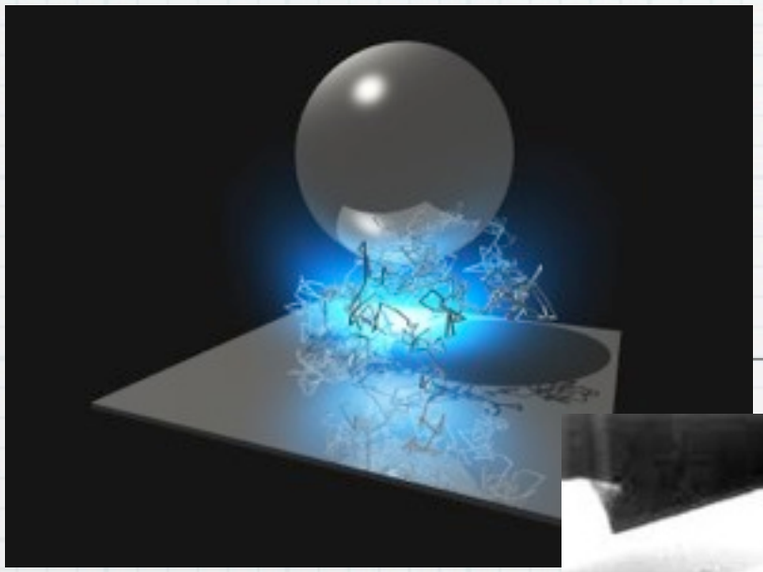
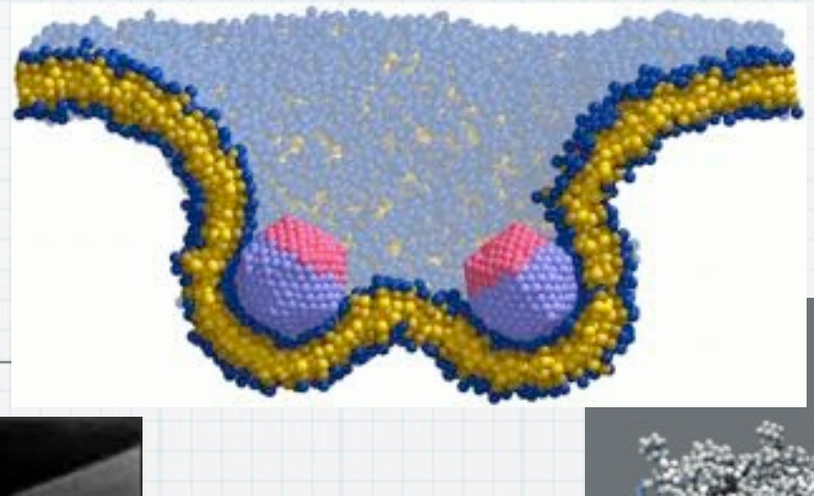
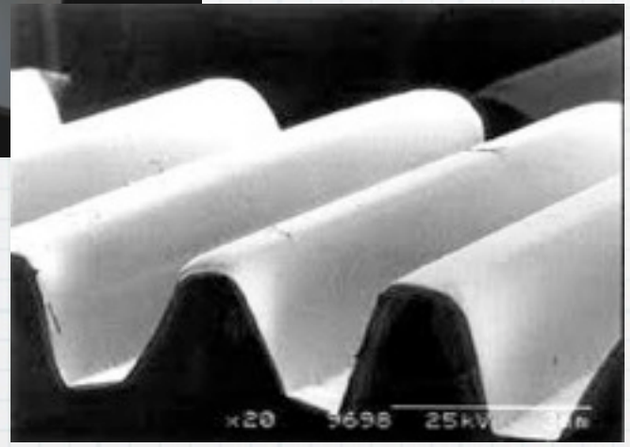
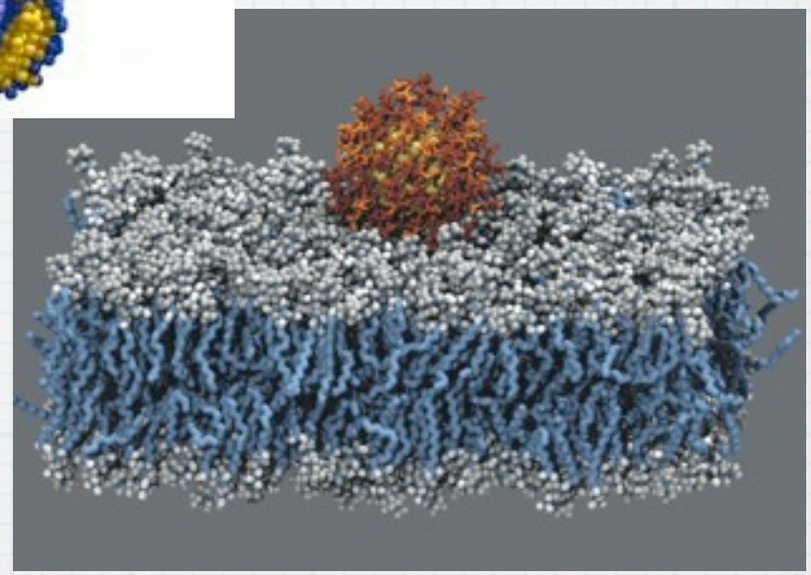
Fluctuation Induced Forces: Theory and Experiment at UCR







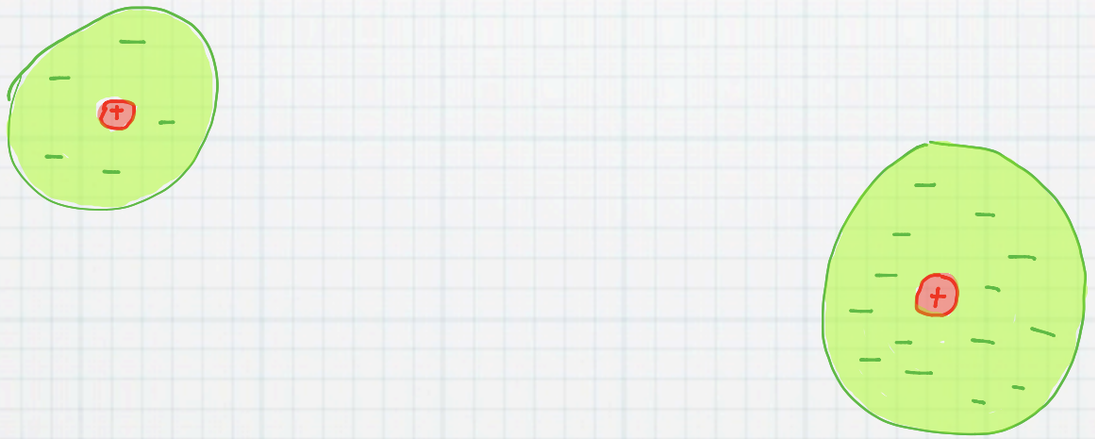


Presented by postdoc Jef Wagner: Professors Umar Mohideen and Roya Zandi

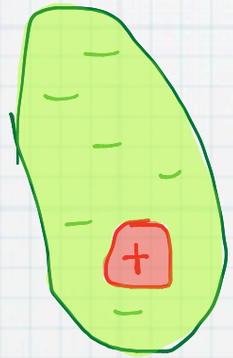
Outline

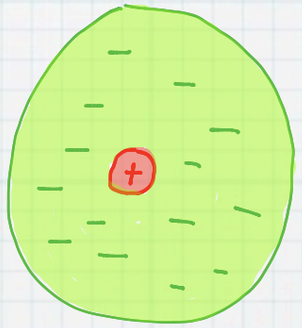
* Background
* Motivation
* E&M Casimir Effect
* Membrane Fluctuations

London Dispersion

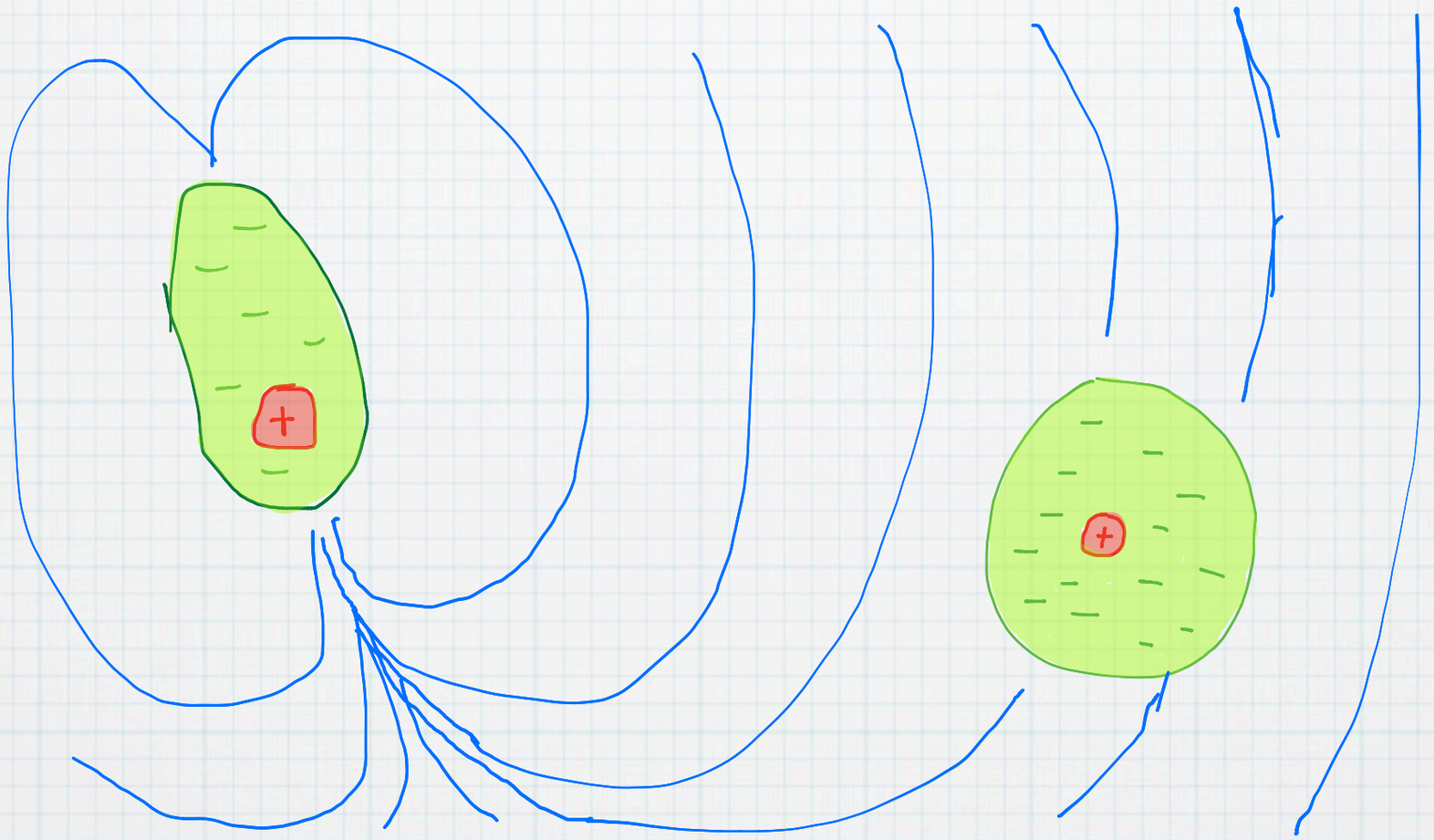


London Dispersion

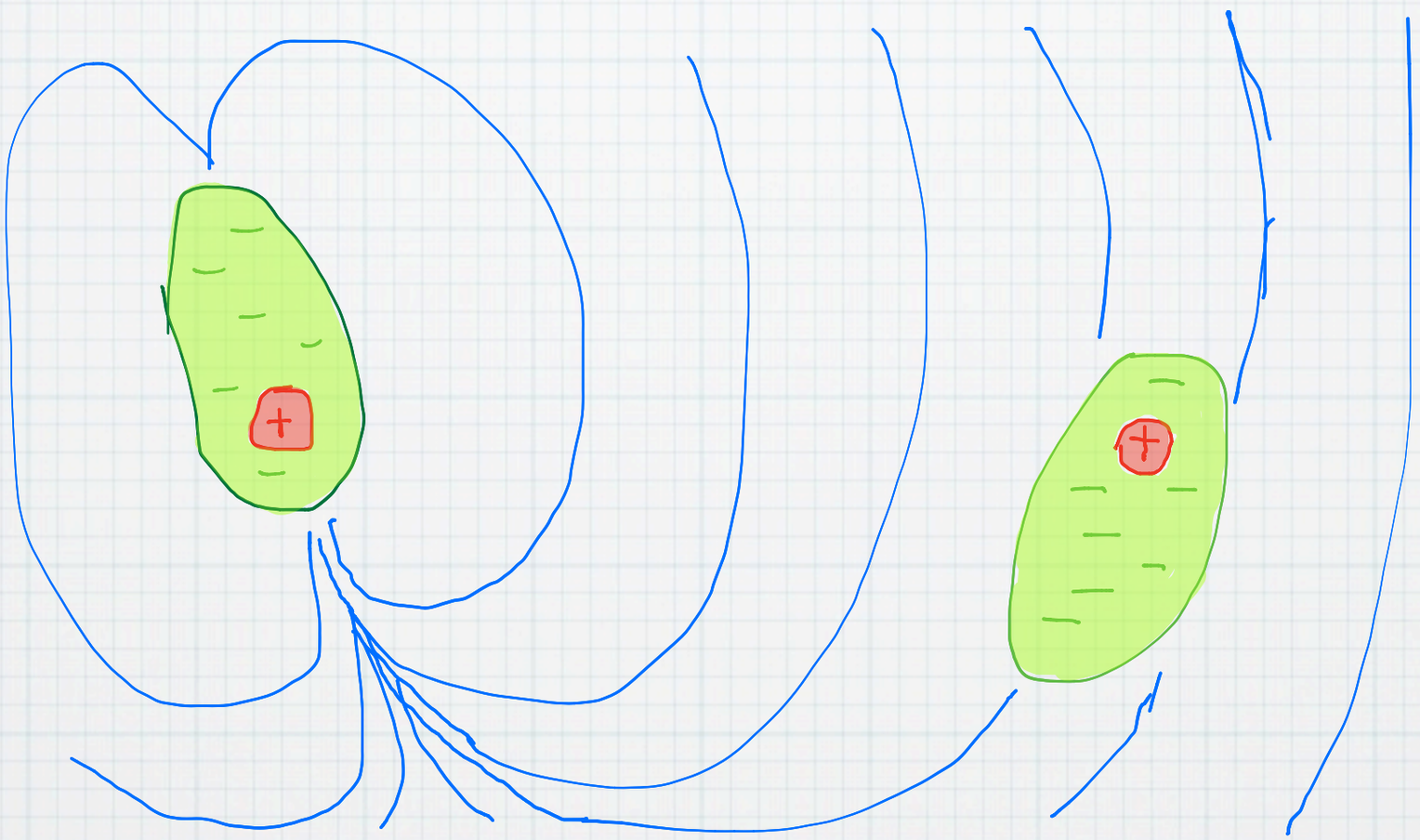




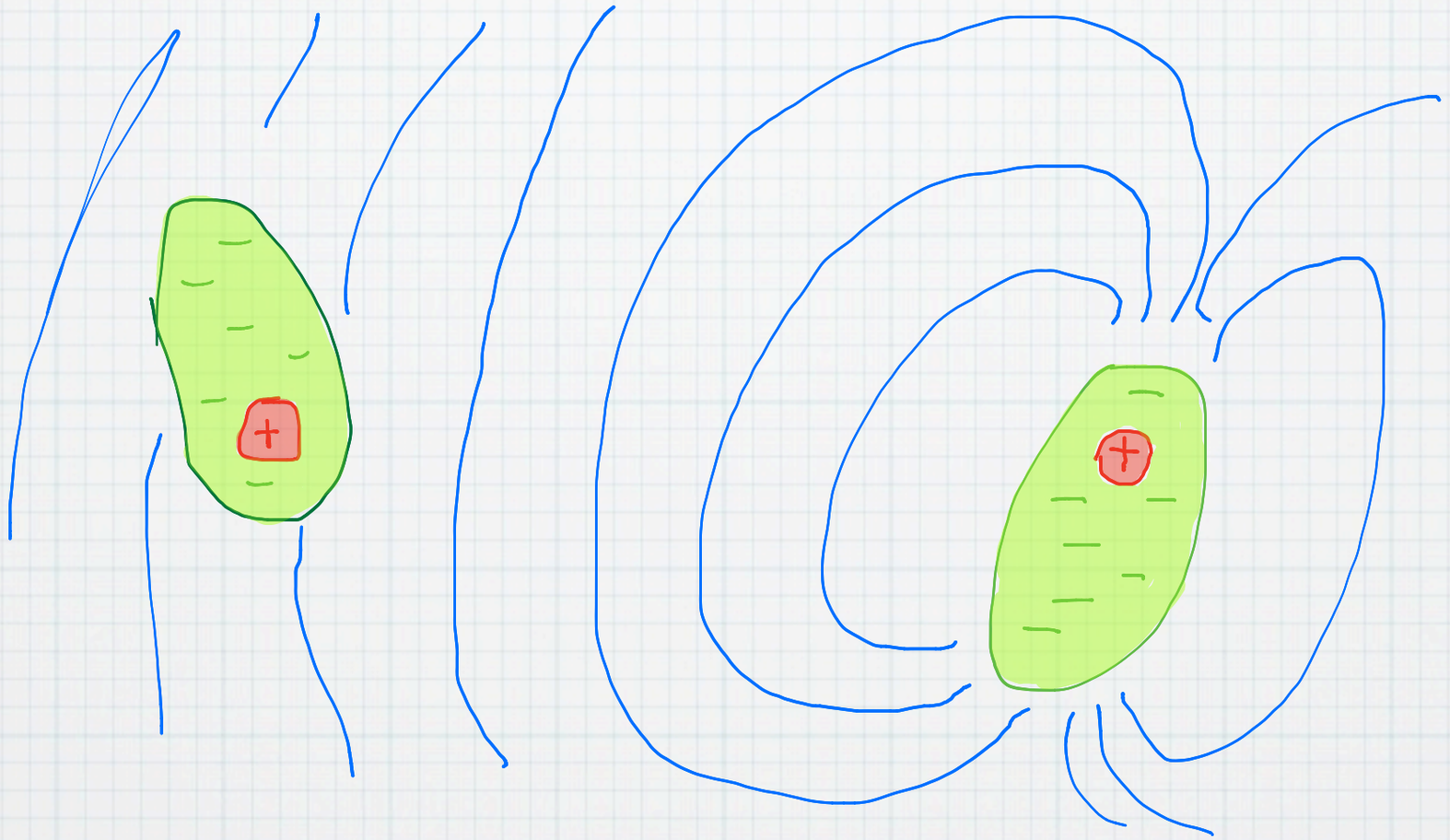
London Dispersion



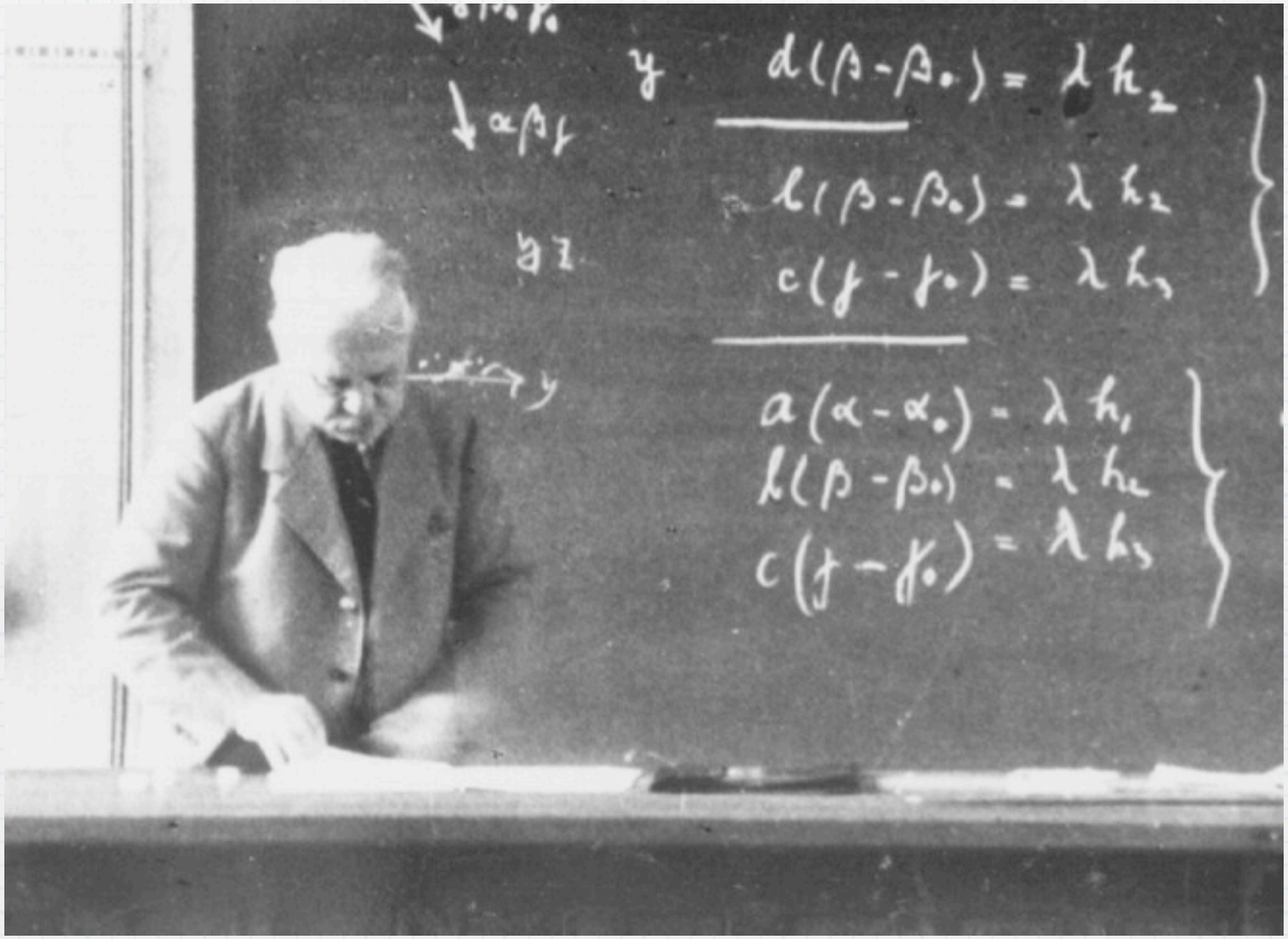
London Dispersion



London Dispersion

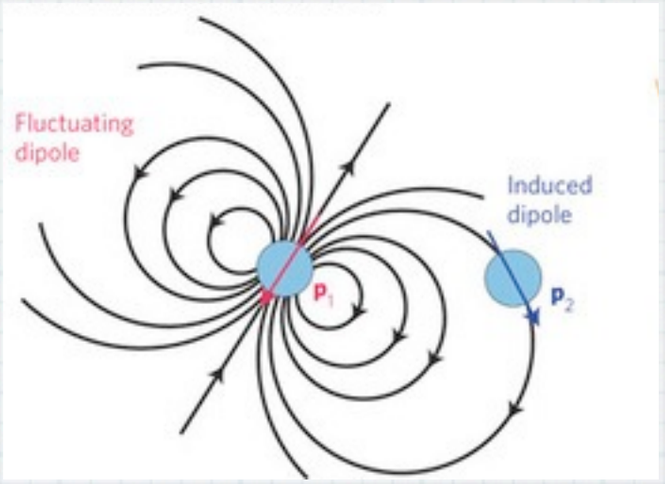


Blackboard Work

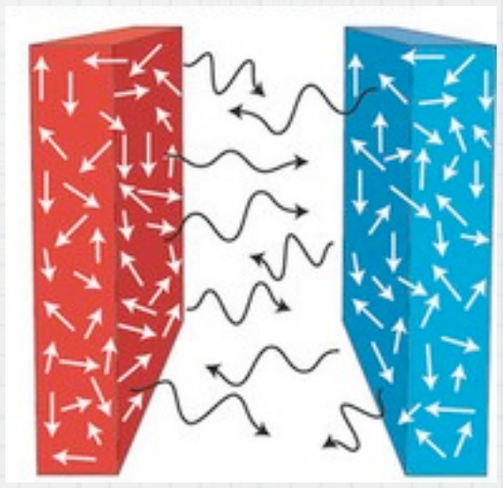


Generalized Fluctuation Induced Forces

* Source of fluctuations
  * Quantum fluctuations
  * Thermal fluctuations

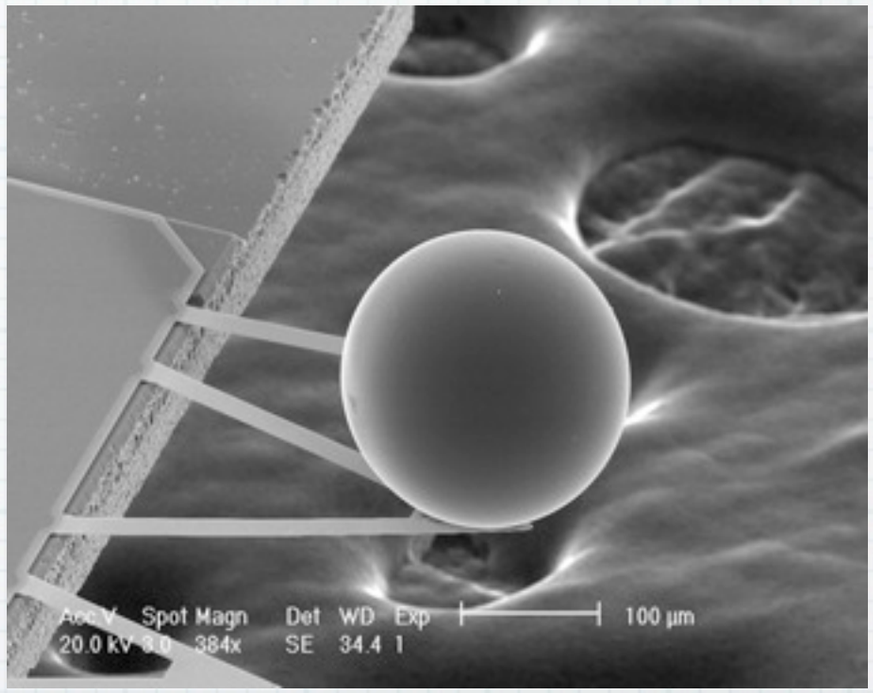


* Objects that interact with the fluctuations
* Objects that otherwise don't interact can interact

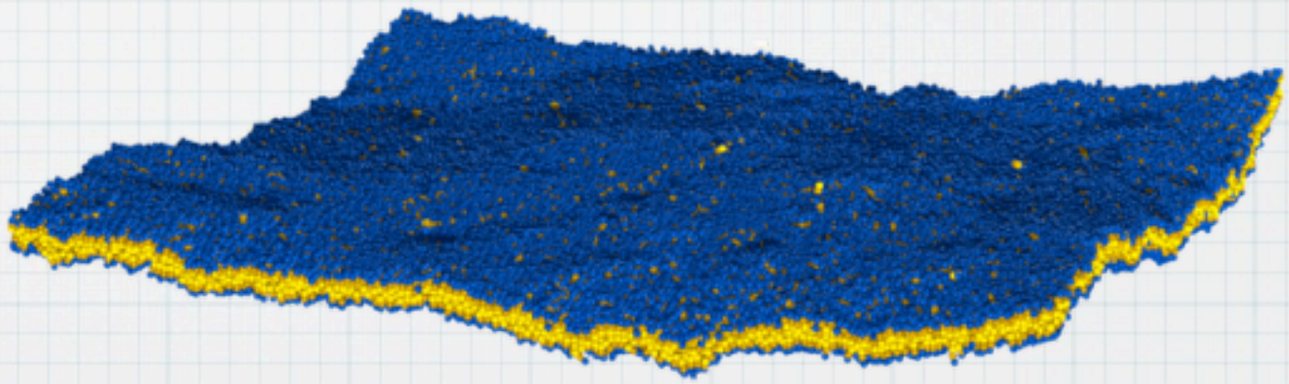


Two systems studied at UCR

* Electromagnetic Casimir Effect

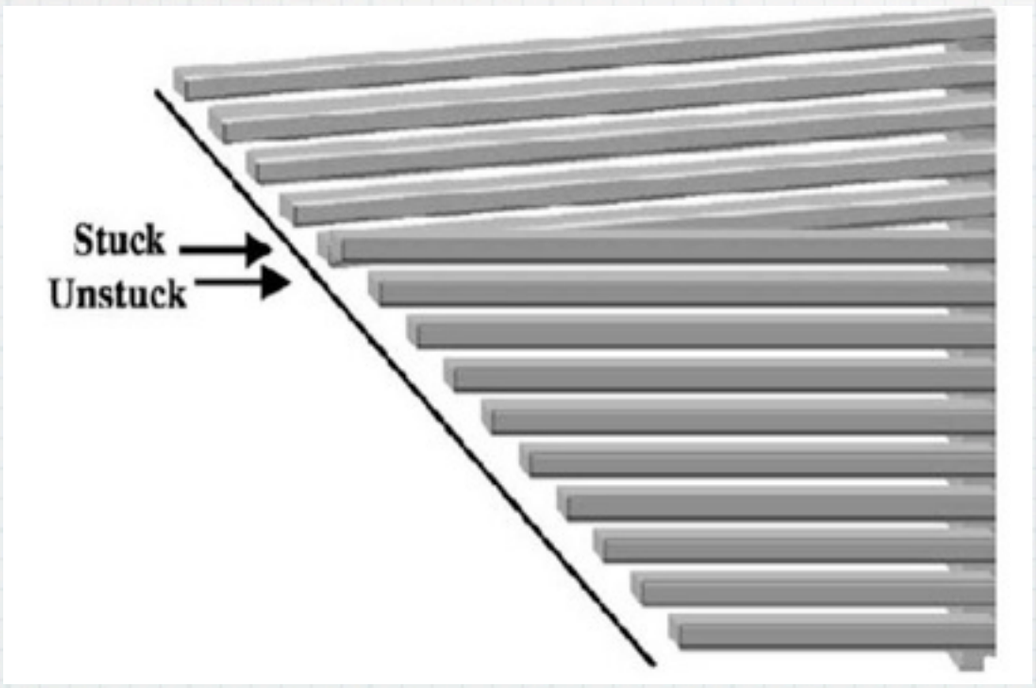


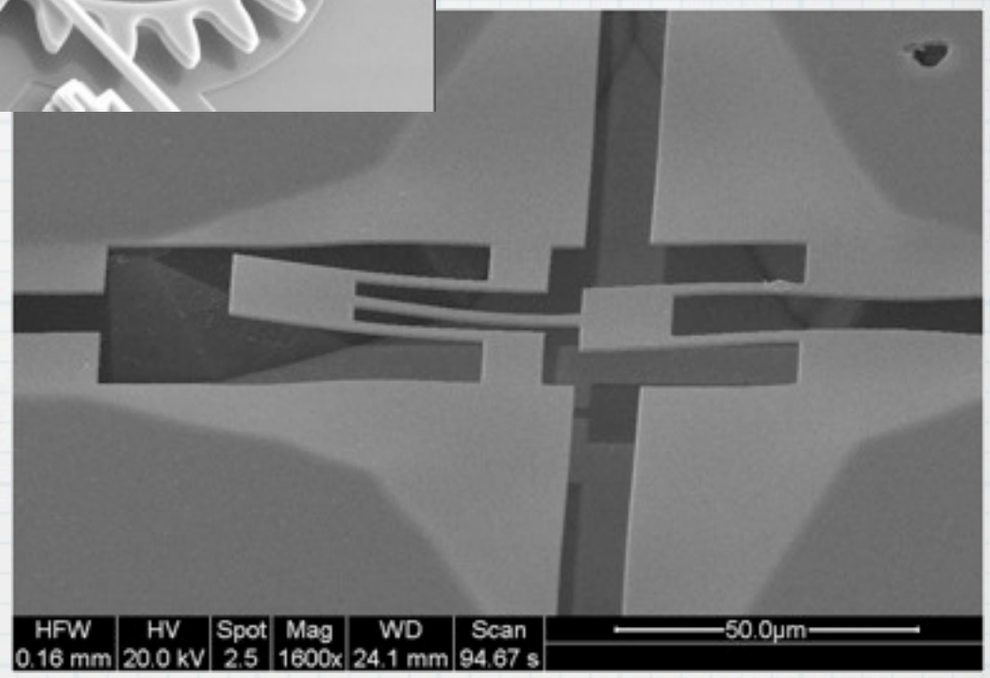
* Fluctuating membrane



Motivation: E&M

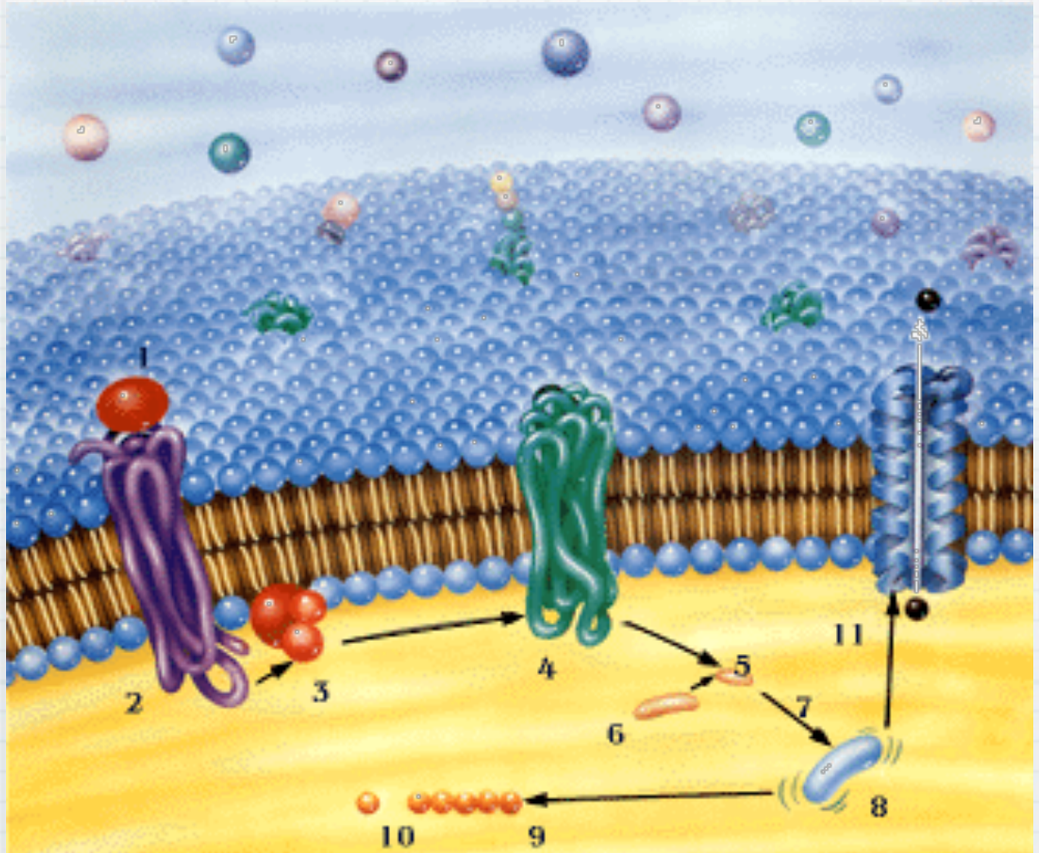
* MEMS and NEMS
* "Stiction"





Motivation: Membrane

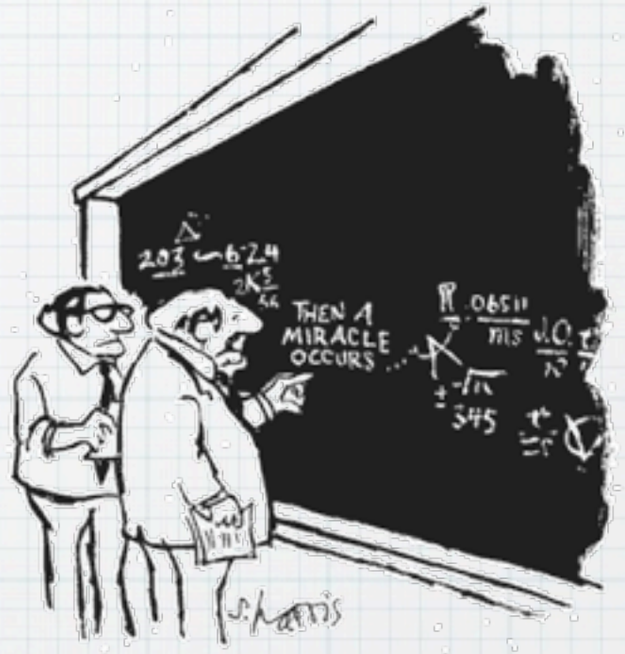
* Proteins in cell membrane



E&M Casimir Effect

* Explain and Demonstrate control of the Casimir effect through the materials and geometry of the system

Theory



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

Experiment

Theory

* Scattering Formalism

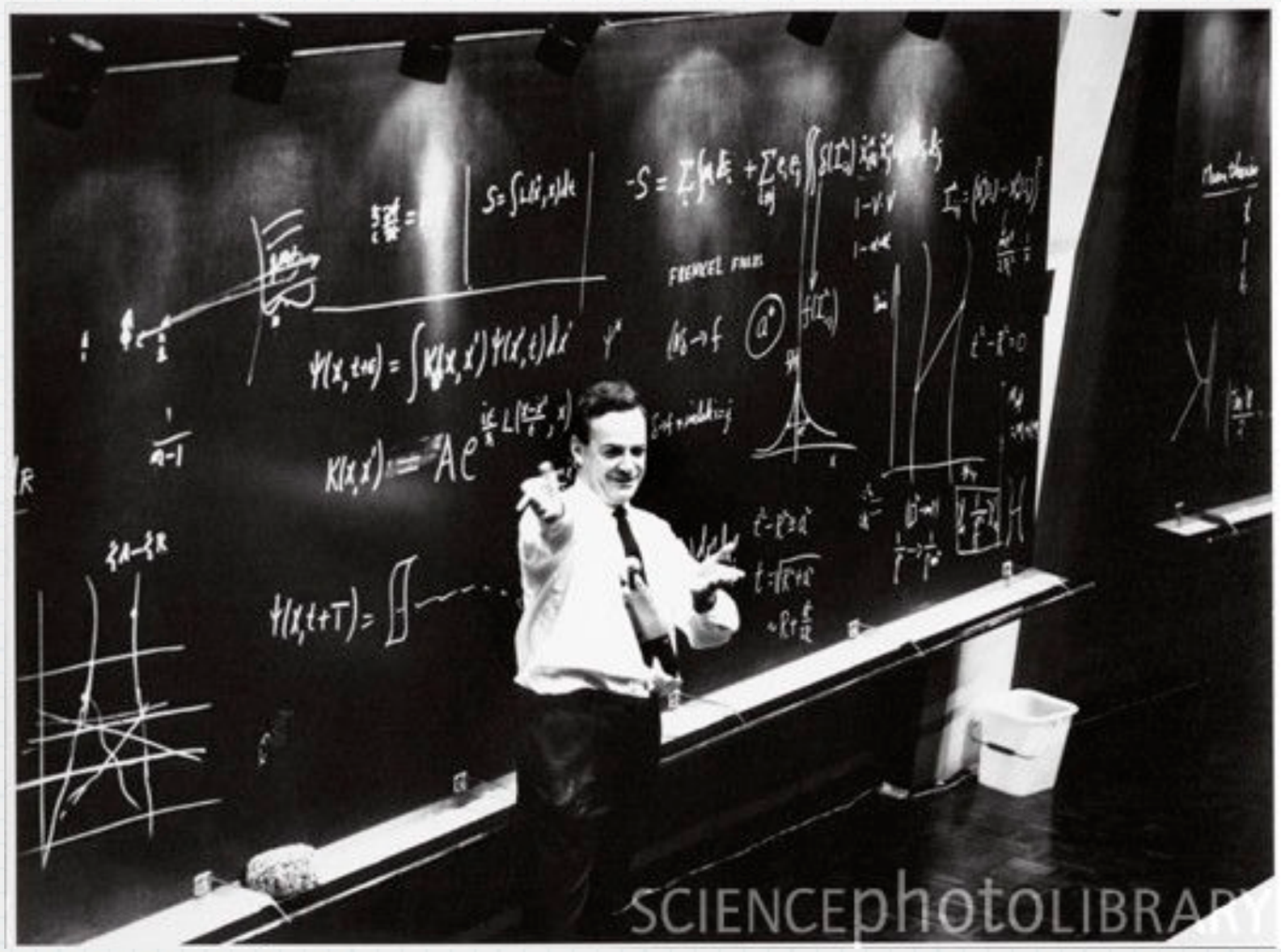
$$U = \frac{\hbar c}{2} \ln \det \left(1 - \mathbb{T}\mathbb{U}\mathbb{T}\mathbb{U}\right)$$

  * T matrix: how the object responds to electromagnetic waves
  * U matrix: how the wave propagates between objects

* Lifshitz Formula

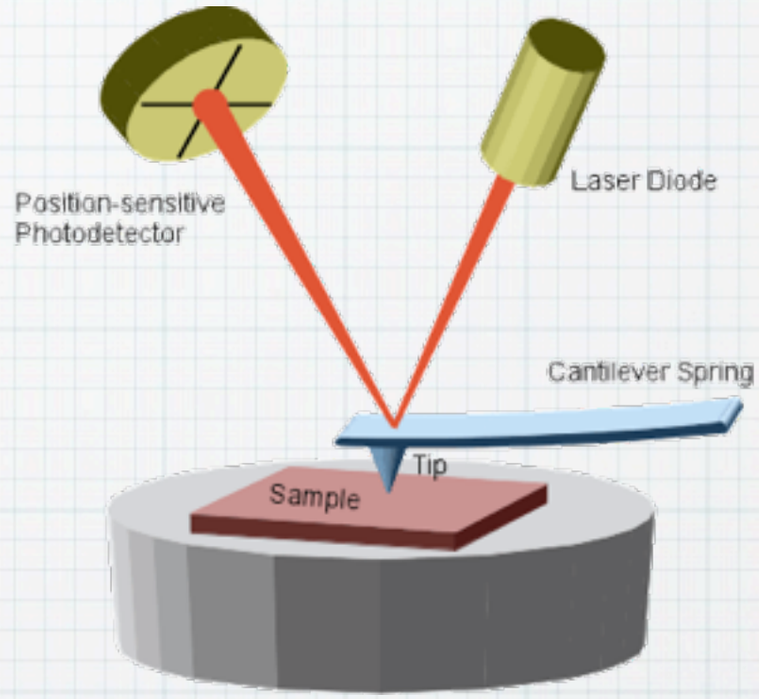
$$\frac{U}{A} = \frac{\hbar c}{2} i \int \mathrm{d}\omega \int \mathrm{d}^2 k \ln \left(1 - r_1 r_2 e^{i\sqrt{n^2\omega^2 - k^2}}\right)$$

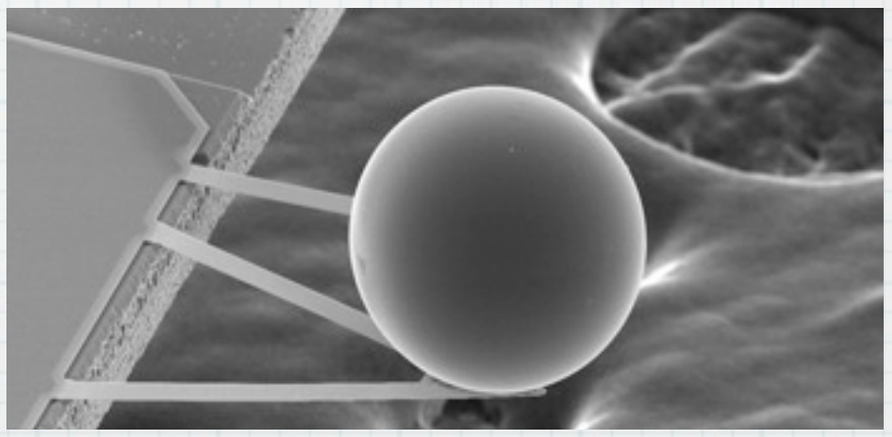
Blackboard Work



Experiments

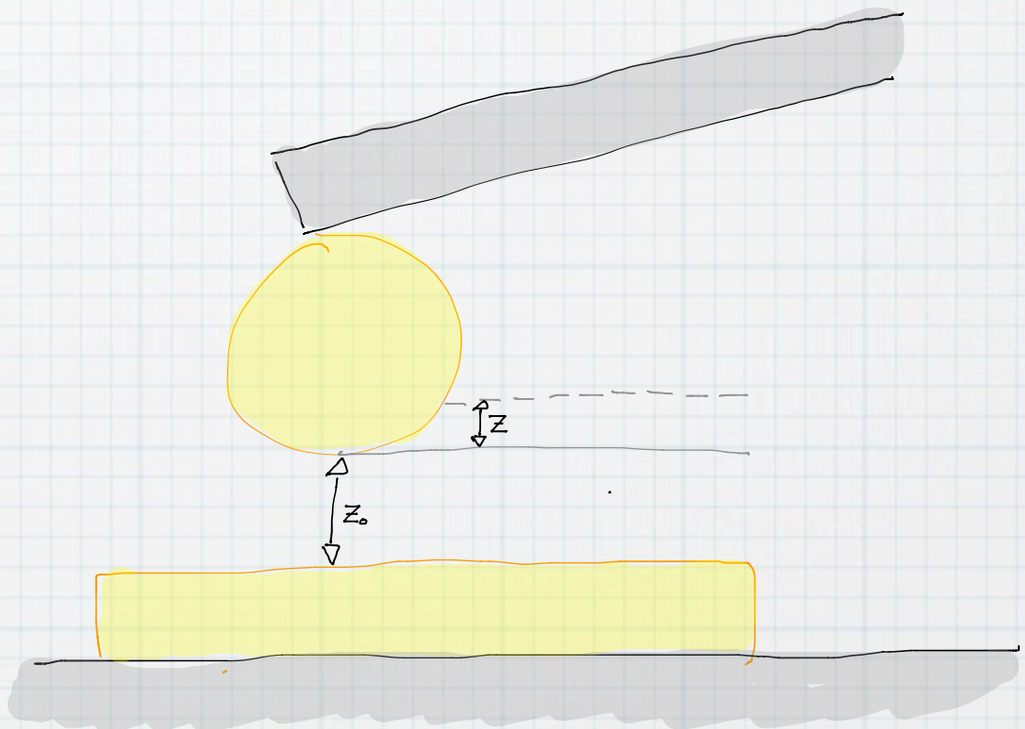
* Use an Atomic Force Microscope (AFM)
* Attach a Sphere to the AFM Cantilever





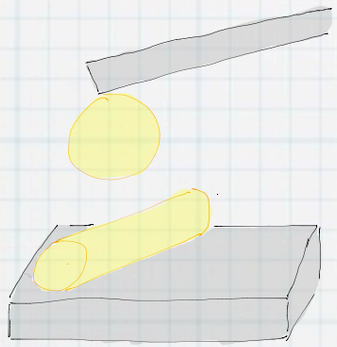
Experiment Calibration

* Only directly measure force and relative separation
* Use electrostatic force to calibrate absolute distance

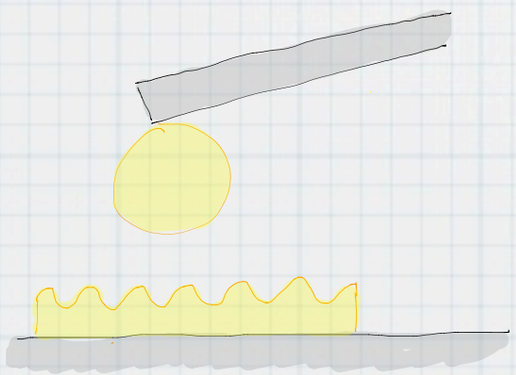


Experiments

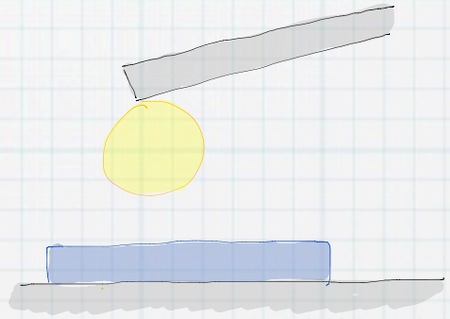
* Shape
  * Cylinder



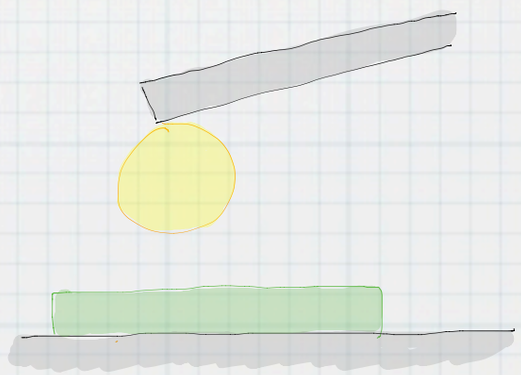
  * Corrugated



* Material
  * Semiconductor

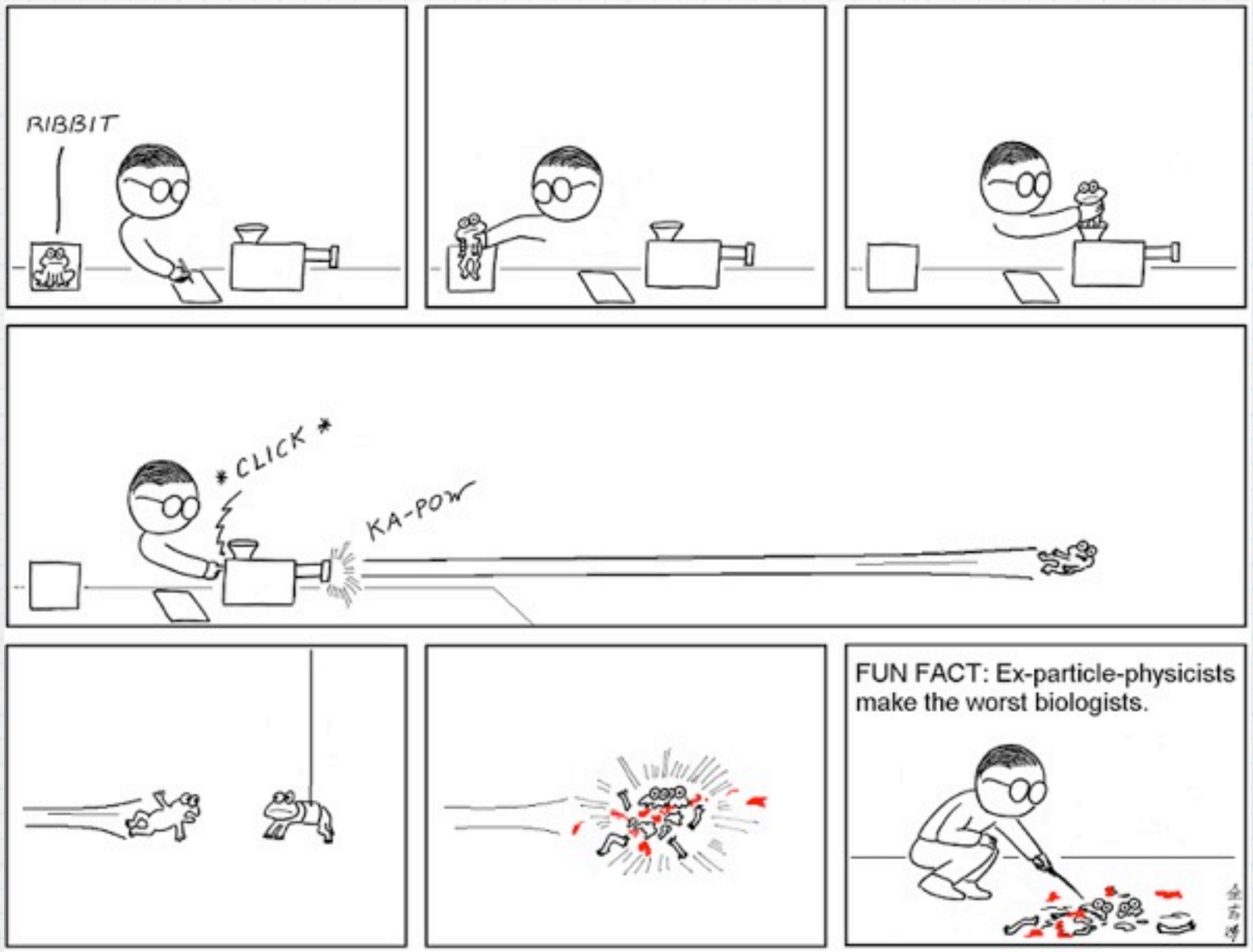


  * Magnetic material

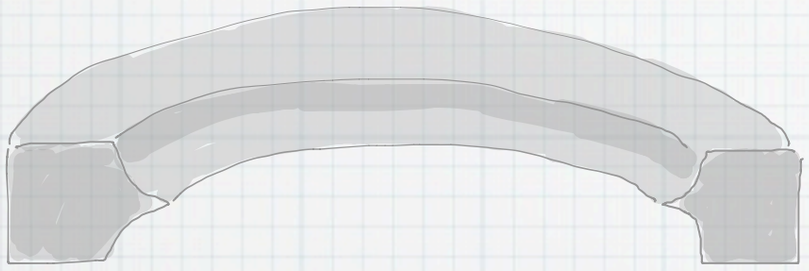


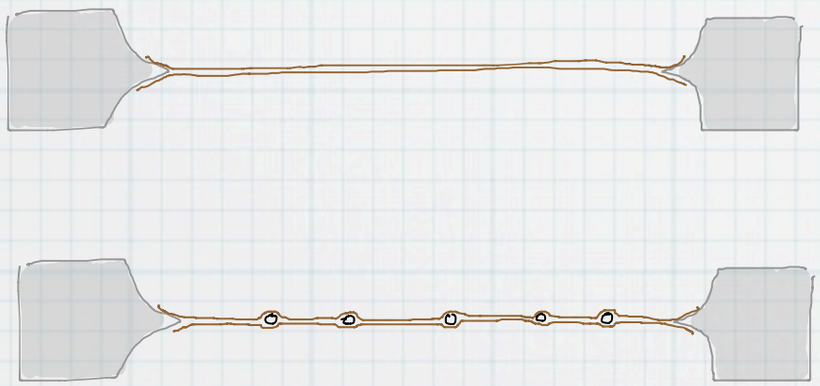
Membrane Experiment

* Demonstrate the presence of fluctuation induced forces



Experimental Setup

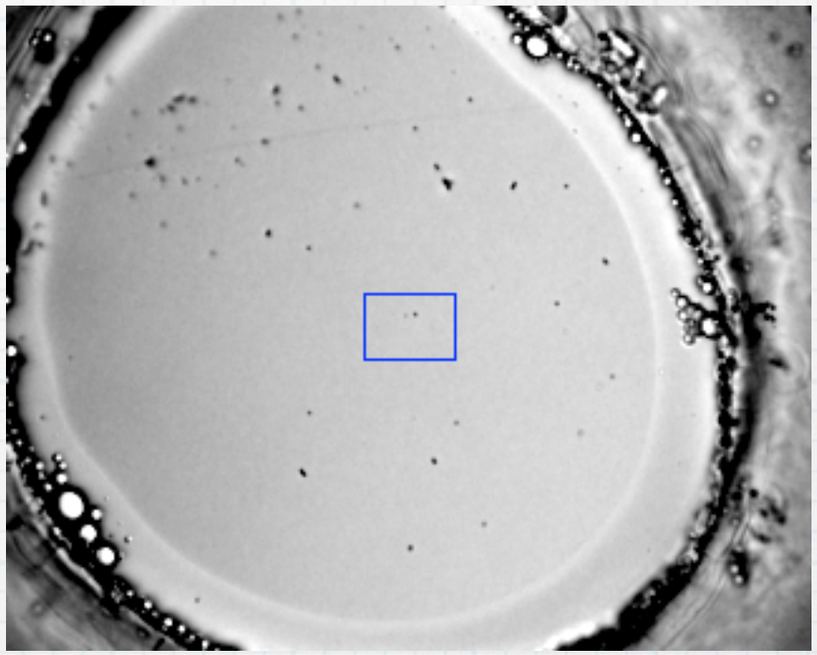


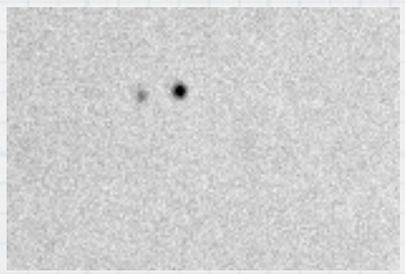


* Form membrane in a teflon ring
* Add functionalized beads
* Video the diffusion of the beads

Videos

* The beads undergo Brownian motion





Analysis

* Identify "good" or "clean" data
  * Most beads are too far apart
  * Some beads are noticeably drifting
* Video of diffusion = Find force on beads

Summary

* E&M Casimir force
  * Demonstrate control
* Membrane fluctuation induced force
  * Demonstrate existence