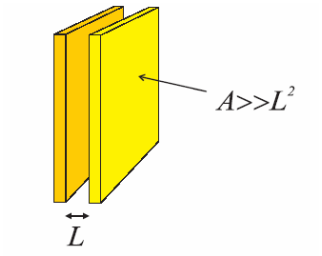
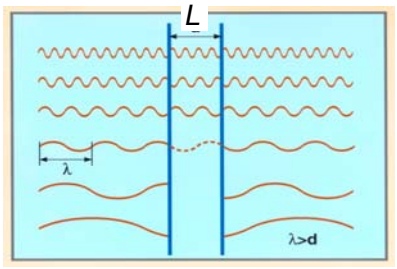
Casimir Effect

Force between to **perfect mirror plates**:





Casimir force (Casimir, 1949)

$$E_C = -\frac{\pi^2 \hbar c}{720 L^3} A \qquad F_C = -\frac{\pi^2 \hbar c}{240 L^4} A$$

$$P_{cas} \equiv \frac{F_{cas}}{A} \approx -10^{-3}\,\text{Pa} \times \left(\frac{\mu\text{m}}{\text{L}}\right)^4$$

$$L = 10\,\text{nm} \qquad P_{cas} \approx -10^5\,\text{Pa}$$

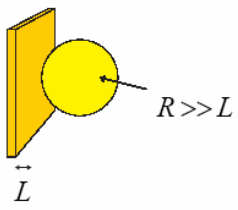
Two plate geometry experimenally very difficult.

Use plate + sphere instead:
→ more difficult to calculate.

Casimir force for plane-sphere geometry

- Older calculations use „proximity force approximation“
- contribution of the surface elements are summed up independently

$$F_{PS} = \int d^2x \frac{F_C(x)}{A}$$



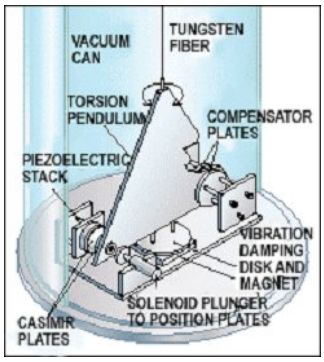
For R >> L:

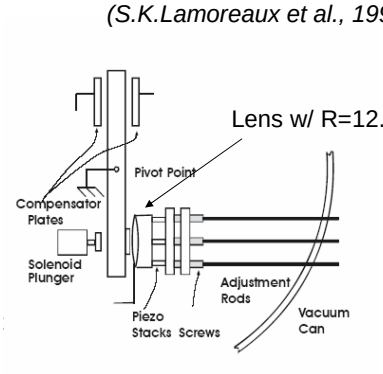
$$F_{PS} = 2\pi R \frac{E_C}{A} = -2\pi R \frac{\pi^2 \hbar c}{720 L^3}$$

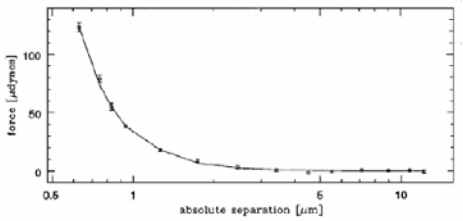
First „modern“ experiment

(S.K.Lamoreaux et al., 1997)

Torsion pendulum,
electrostatically compensated





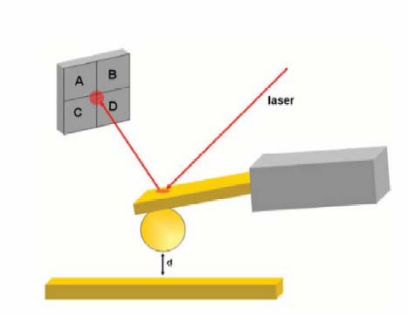


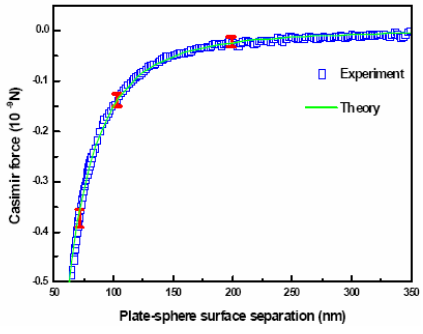
S. K. Lamoreaux, U of Washington, Seattle
Phys.Rev.Lett. 78(1997)5, subm. 28. 8. 1996

Atomic force microscope

Riverside experiment

- Plane-sphere geometry
- Polysterene Sphere (100 μm) and plane covered with gold
- Distance 60 – 900 nm
- Optical readout
- Experimental accuracy better than 2% at smallest separation

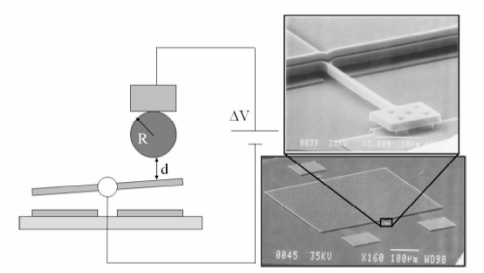




U. Mohideen, A. Roy,
Phys. Rev. Lett. 1998, 81.

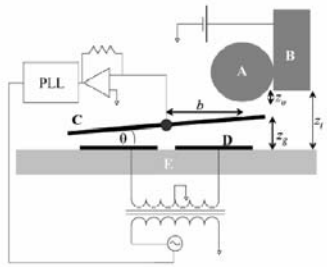
Modern Torsion Experiments

Capasso et al.



- Sphere (100 μm) and plane covered w/ gold
- Distance 100 … 500 nm
- Capacitive readout

Fischbach et al.



- Au coated sphere (100…600 μm)
- Cu coated plate, distance 260 … 1200 nm
- Static or dynamic readout

Recently, many experimental groups study Casimir forces for different materials and shapes – why ??

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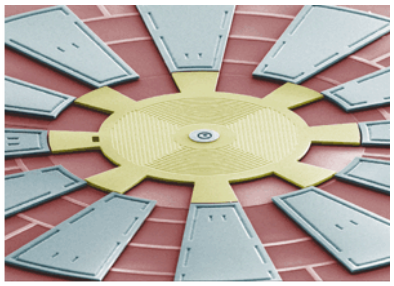
Influence of the Casimir force on MEMS and NEMS

Microelectromechanical Systems (MEMS)
Nanoelectromechanical Systems (NEMS)

fully integrated, miniature sensors and actuators with typical distances between parts of less than 1μ



Electrostatic micromotor fabricated from silicon.

Casimir force can cause mechanical elements to collapse onto nearby surfaces, resulting in permanent adhesion — an effect called **'stiction',**

Are there ways to engineer M/NEMS in which the Casimir forces are repulsive ?
→ NEMS would be immune to stiction

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Quantum levitation by left-handed metamaterials

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Abstract. Left-handed metamaterials make perfect lenses that image classical electromagnetic fields with significantly higher resolution than the diffraction limit. Here, we consider the quantum physics of such devices. We show that the Casimir force of two conducting plates may turn from attraction to repulsion if a perfect lens is sandwiched between them. For optical left-handed metamaterials, this repulsive force of the quantum vacuum may levitate ultra-thin mirrors.

"Our result means we could now envision frictionless machines or novel micromotors."

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