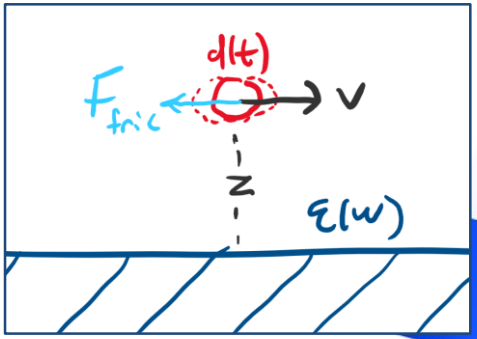
Casimir Friction at Finite Temperature

Aaron Swanson
Dr. Kim Milton
Casimir Physics Group

What is Casimir Friction?

- When an atom travels parallel to a dielectric slab with some v, it experiences lateral "friction"
- Analyze dissipation of energy (i.e. friction) due to interaction of fluctuations
- GOAL: Introduce temperature to determine chance of experimental verifiability



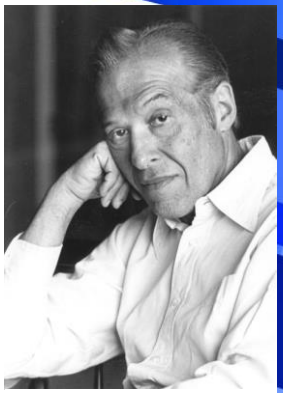
$$f_{T=0} = -\frac{135\alpha_0^2 v^3}{4\pi^3\sigma^2(2z)^{10}}$$

Formalism: The Effective Action

- The Master Equation:

$$A_{\text{eff}} = \frac{1}{2}\int \mathrm{d}^4x\ \mathrm{d}^4x'\ \langle \mathrm{T}[P(x)P(x')]\rangle\ i\,\langle \mathrm{T}[E(x)E(x')]\rangle$$

- Correlation function: gives degree of correlation between its two arguments
- Within each correlation function, fluctuations are uncoupled from each other
- Need to know more information about the interaction to proceed



Julian Schwinger

Formalism: Interactions/Dissipation

- Fluctuation-dissipation theorem (FDT) equates correlation functions to causal, thermal dissipation:

$$\langle \mathrm{T}[d(t)d(t')]\rangle = \int \frac{\mathrm{d}\omega}{\pi}(n_\omega + 1)\,\mathrm{Im}\alpha(\omega)\,e^{-i\omega|t-t'|}$$

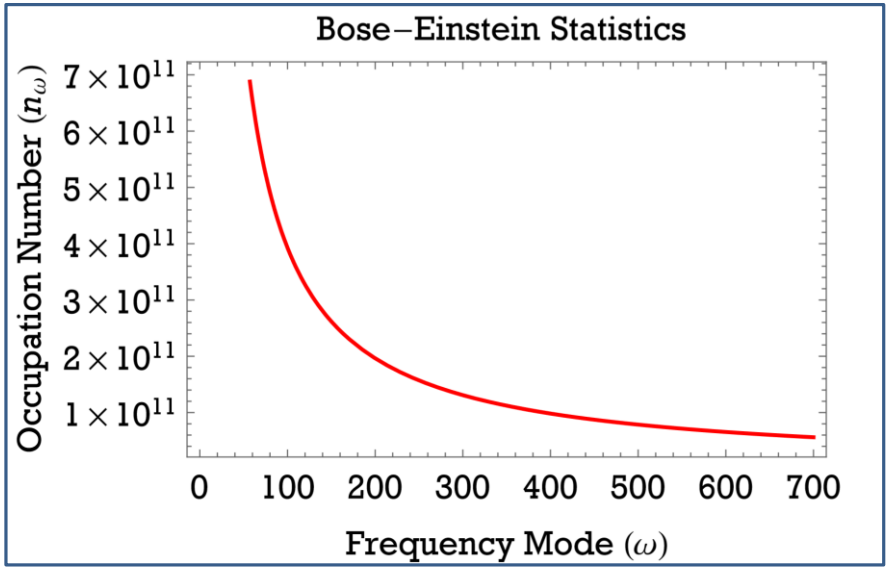
- Causality occurs between dipole and slab

$$d(t) = \int_{-\infty}^{t} \mathrm{d}t'\ \alpha(t-t')E(t')$$

$$E(t) = \int_{-\infty}^{t} \mathrm{d}t'\ \Gamma(t-t')d(t')$$

Formalism: Temperature/Dissipation

- Temperature increases dissipation of energy (and thus friction)
- Modeled via Bose-Einstein statistics



Road Map to Friction Result

- Develop scheme to extract inherently dissipative force
- Calculate additional terms (involving magnetic dipoles)
- Plug in Green's function and polarizability, and **integrate**
- Obtain "complete" results and compare with others

Sources

''Resource Letter VWCPF-1: van der Waals and Casimir-Polder forces,'' K.A. Milton, Am. J. Phys. 79, 7 (2011)

''On the Attraction Between Two Perfectly Conducting Plates,'' H. B. G. Casimir, Proc. Kon. Ned. Akad. Wetensch. 51, 793–795 (1948)

''The Influence of Retardation on the London-van der Waals Forces,'' H. B. G. Casimir and D. Polder, Phys. Rev. 73, 360–372 (1948).

''The Theory of Molecular Attractive Forces Between Solids,'' E. M. Lifshitz, Zh. Eksp. Teor. Fiz., 29, 94–110 (1955) [English transl.: Soviet Phys. JETP 2, 73–83 (1956)].

''The Reality of Casimir Friction,'' K.A. Milton, J.S. Høye, and I. Brevik, Symmetry 8, 29 (12 pages) (2015).

''Casimir friction between polarizable particle and half-space with radiation damping at zero temperature,'' J.S. Høye, I. Brevik, K.A. Milton, J. Phys. A 48, 365004 (15 pages) (2015)

''Casimir Effect in Dielectrics,'' J. Schwinger, L. L. DeRaad, Jr., and K. A. Milton, Ann. Phys. (N.Y.) 115, 1–23 (1978).

Quantum Field Theory for the Gifted Amateur, T. Lancaster and S. J. Blundell, 1st ed (Oxford, Oxford, 2014)

Statistical Physics, Part 1, L. Landau and E. M. Lifshitz, 3rd ed (Pergamon, Oxford, 1980).

Web Image Sources

http://www.calphysics.org/images/casimir.jpg

https://upload.wikimedia.org/wikipedia/commons/thumb/b/bd/Hendrik_Casimir_%281958%29.jpg/266px-Hendrik_Casimir_%281958%29.jpg

https://fr.cdn.v5.futura-sciences.com/builds/images/rte/RTEmagicC_28069_Lifshitz_The_MacTutor_History_of_Mathematics_archive_txdam19697_9dd4e4.jpeg

http://www.ipam.ucla.edu/wp-content/uploads/2017/03/Julian-Schwinger.jpg