

LETTERS

VACUUMS, RETARDATION AND CASIMIR INTERACTIONS

In his October 1990 Reference Frame column (page 9) Daniel Kleppner presents "a matchbook calculation of the van der Waals force and some of its cousins," using the fact that a harmonic oscillator has a zero-point energy $\hbar\nu/2$. He does this "with apologies to [Hendrik] Casimir for doing crudely today what he did elegantly more than 40 years ago." It might be worth noting that Fritz London gave the same matchbook-style calculation more than 50 years ago.¹ As London noted, "We need not know much quantum mechanics in order to discuss our simple model. We only need to know that in quantum mechanics the lowest state of a harmonic oscillator of the proper frequency ν has the energy $\hbar\nu/2$."

Having long labored in the vacuum vineyards, I fully agree with Kleppner's conclusion that "one must take the vacuum seriously." I am less enthusiastic about the implication that recent experiments with two-state atoms in resonant cavities do much to reinforce this conclusion. Observations of Jaynes-Cummings oscillations and inhibited spontaneous emission are delightful accomplishments and confirm that two-state systems behave as they are supposed to according to elementary quantum mechanics, but it is difficult to see what fundamentally new insights they have instilled about the vacuum. Jaynes-Cummings oscillations, for instance, are explained by simplifying the radiative transition theory of the textbooks to the case of a single field mode. Inhibited spontaneous emission results simply from the fact that if there is no cavity mode at a radiator's frequency, there can be no radiation at that frequency.

With apologies to Kleppner, I see no reason to raise the issue of the vacuum in such experiments, aside from the fact that spontaneous emission has been known for many years to be connected with vacuum field fluctuations. Moreover, although Casimir is undoubtedly "pretty smart," as Kleppner writes, his effects are by no means the first or most important

examples of the use of the zero-point energy introduced by Planck. Have we forgotten that the Lamb shift and the electron g factor are attributable in large part to vacuum fluctuations and lost sight of such beautiful "matchbook" calculations as Feynman's argument that the Lamb shift arises from the change in zero-point energy due to the mere presence of the atom?

Reference

1. F. London, *Trans. Faraday Soc.* **33**, 8 (1937). M. Born, *Atomic Physics*, 4th ed., Hafner, New York (1935), p. 358.

PETER W. MILONNI

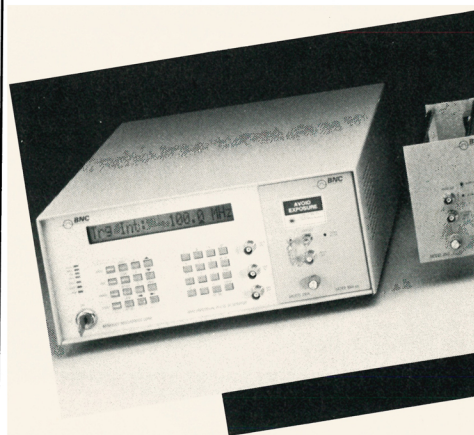
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Anything written by Daniel Kleppner can be expected to be very interesting, and his Reference Frame column "With Apologies to Casimir" certainly is. Since a few of his statements on the nature of a Casimir interaction potential, V_{Cas} , could possibly be misread, however, some remarks might be in order. Retardation effects are not small, but infinitesimal, potatoes for (nonrelativistic) potentials such as the van der Waals interaction at intermediate distances. But they are the whole meal for a V_{Cas} . The Casimir interactions we will discuss are of quantum electrodynamic origin, but unlike most QED effects they are long range or, equivalently, retarded. Remarkably, even if $v \ll c$, where v is a characteristic velocity of the particles of the interacting systems, the c dependence does not enter as a correction of order v^2/c^2 ; rather, the very r dependence of the leading term of the (now c -dependent) interaction is altered.

There are relatively clear retardation effects on the interaction $V(r)$ of two hydrogen atoms or of a bound outer electron and the He^+ core in a helium atom. $V(r)$, which is nonrelativistic at small r , changes when the transit time $\tau = 2r/c$ of a photon between H and H or between e^- and He^+ approximates an orbital period of an electron, $P \approx 2\pi a_0 / (e^2/\hbar)$ —that

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is, for $r \approx 137a_0$. In the case of the two H atoms, the $1/r^6$ van der Waals interaction becomes the c/r^7 Casimir-Polder interaction. In the case of e^- and He^+ , a $1/cr^5$ term appears, as shown by E. J. Kelsey and me.¹ An improved theory by C. K. Au, G. Feinberg and J. Sucher,² valid down to smaller values of r , and supplemented by work by R. J. Drachman³ and G. W. F. Drake,⁴ is, after herculean efforts by S. R. Lundeen and collaborators,⁵ within a laser's edge of providing the first high-precision confirmation of a Casimir interaction. (See my article in *PHYSICS TODAY*, November 1986, page 37, and references therein.)

The best known Casimir effect is the force per unit area between uncharged parallel ideal plates at a separation z . Retardation effects are less transparent for this case. One concludes dimensionally that $F/A = K\hbar c/z^4 = (F/A)_{\text{Cas}}$, with K a constant, for all z , with no change of form: Retardation is crucial for all separations. An ideal conductor adjusts, with period $P = 0$, to any electric field present, and $\tau = 2z/c \gg P$ for all z . In a real conductor, where the smallest period (or characteristic decay time) P is nonzero, $F/A \sim (F/A)_{\text{Cas}}$ for $\tau \gg P$, that is, for $z \gg cP/2$, but for $z \ll cP/2$ retardation is irrelevant and F/A is independent of c and characteristically goes as $1/z^3$.

I would like to thank Kleppner for some useful conversations.

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1. E. J. Kelsey, L. Spruch, *Phys. Rev. A* **18**, 15 (1978).
2. C. K. Au, G. Feinberg, J. Sucher, *Phys. Rev. Lett.* **53**, 1145 (1984).
3. R. J. Drachman, *Phys. Rev. A* **26**, 1228 (1982).
4. G. W. F. Drake, *Phys. Rev. Lett.* **65**, 2769 (1990), and references therein.
5. E. A. Hessels, F. J. Deck, P. W. Arcuni, S. R. Lundeen, *Phys. Rev. Lett.* **65**, 2765 (1990), and references therein; erratum, *Phys. Rev. Lett.* **66**, 2549 (1991).

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KLEPPNER REPLIES: The term "Casimir effect" is often used loosely, and perhaps I used it too loosely in motivating my discussion of the van der Waals interaction. Larry Spruch's observation that retardation can never be ignored when considering the attraction of ideal conducting plates justifies his taking me to task for downplaying retardation or, alternatively, for not distinguishing between the Casimir force and the van der Waals force.

With respect to Peter Milonni's bewilderment at the excitement over cavity QED experiments, I can appreciate his point of view, for many of the basic physical principles were spelled out in his early work on atoms radiating between mirrors—work that was far ahead of experiment. Milonni correctly points out that physical effects of the vacuum are hardly news in physics, and that none of the recent generation of experiments can compete with, for instance, the drama of the Lamb shift. Although I did not labor the point, my comments on cavity quantum electrodynamics were in the context of macroscopic quantum mechanics. Whether or not the observation of the Jaynes-Cummings oscillations should be cause for excitement is, of course, a matter of taste. However, when an area becomes experimentally accessible—even one for which the theory is already beautifully developed—new phenomena are likely to be discovered. This has certainly been the case for cavity QED.

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Trends and Tactics in Science Funding

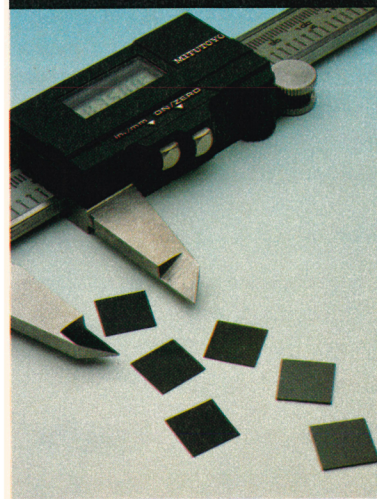
In their article on young physics faculty in 1990 (February, page 37) Roman Czujko, Daniel Kleppner and Stuart A. Rice report that there has been a dramatic drop between 1977 and 1990 in the fraction of young faculty who believe that research funding is adequate. Their report joins a rising tide of complaint about the plight of academic research in the US today. Leon Lederman, president of the AAAS, has reported on a survey of the views of 250 academic researchers; he too found a dismal state of morale among them.

The chart on page 136 shows the trend from 1973 through 1987 in support for research and development per doctoral degree holder in the physical sciences (mainly physics, chemistry and astronomy) employed in an academic institution. The curious fact is that young physics faculty felt better in 1977, after several years of diminishing support, than after the sustained growth in *per capita* support during the 1980s.

The explanation of this curious phenomenon is not obvious. Similar trends occurred in the support of academic life sciences and other natural sciences. These facts suggest that there may be underlying structural

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