

letters

Relativity and quantum theory

Because my article "The impact of special relativity on theoretical physics" (May, page 34) was prepared in haste and subjected to limited review by others, I overlooked the insightful work of my old friend and office mate in graduate school, Lawrence Biedenharn. In a paper entitled "The 'Sommerfeld puzzle' revisited and resolved," Biedenharn establishes an intimate connection between the relativistic old quantum theory of Arnold Sommerfeld and the relativistic quantum mechanics of Paul A. M. Dirac for the Kepler problem (with its special $O(4)$ symmetry).¹ He shows that the correct correspondence for the nonrelativistic Sommerfeld problem is not the spinless Schrödinger equation, but rather the Schrödinger equation with spin as a dynamically independent variable.

My comment that Sommerfeld's "treatment within the old quantum theory captured the essence of the spinning electron without knowledge of that degree of freedom" is given explicit meaning in Biedenharn's paper, to which I commend you all. I thank Pekka Pyykkö of the University of Helsinki for drawing Biedenharn's work to my attention.

On a separate point, Lee C. Pittenger has kindly pointed out that in discussing wigglers I may have misled the unthinking reader in identifying the wavelength of the periodic magnetic structure rushing by the electron in its rest frame directly with the wavelength of the dipole electromagnetic radiation emitted in that frame. It is of course the frequencies that are the same. The correct statement is that the wavelength of dipole radiation in that frame is $\lambda' = \lambda_u / \gamma\beta$, while the wavelength of the magnetic structure is $\lambda_u' = \lambda_u / \gamma$. In my article, I treated the two as identical, which is legitimate only for γ much larger than 1.

Reference

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7/87

Retarded potentials

I very much enjoyed the article by Larry Spruch, "Retarded, or Casimir, long-range potentials" (November 1986, page 37). However, Spruch adopts the point of view that long-range

van der Waals forces of the Casimir-Polder type arise from the coupling of the systems involved (atom-atom, atom-wall, wall-wall and so on) to the electromagnetic zero-point fluctuations. I would like to point out that this is not the only point of view.

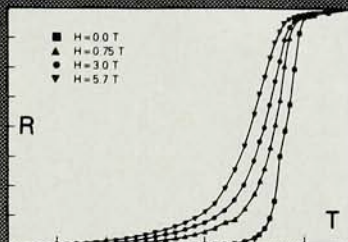
Physical phenomena that are usually explained by the introduction of vacuum fluctuations can also be derived in the absence of such fluctuations if source fields of the systems and corresponding radiation-reaction effects are included instead. For example, in 1927 Paul A. M. Dirac was able to derive the Einstein A coefficient of spontaneous emission by second quantizing the electromagnetic field and interpreting spontaneous emission as arising from the interaction of the atom with zero-point fluctuations.¹ It is less well known that Enrico Fermi, in that same year, was able to arrive at the same result simply by including a nonlinear, radiation-reaction term in Schrödinger's equation.²

The famous Casimir effect, the attractive force between two plates suspended in a vacuum, was first derived by considering energy differences in the vacuum field modes between the plates.³ However, Evgenii M. Lifshitz and his colleagues,⁴ and later Julian Schwinger, Lester De Raad and Kimball Milton,⁵ were able to arrive at Hendrik B. G. Casimir's result—in the absence of any zero-point modes—by including source terms for the plates in a stress-energy tensor. Schwinger and his colleagues were able to get the atom-atom and atom-wall interactions as limiting cases of the wall-wall solution.

More recently Asim O. Barut and his coworkers have advanced a non-second-quantized version of QED that includes the self-fields of the systems from the beginning.⁶ Using this version of QED it has been possible to derive, for example, the atom-wall interaction directly—again in the absence of any vacuum field fluctuations.⁷ On one hand the vacuum fluctuations are viewed as being perturbed by the presence of the wall and thus giving rise to an effective potential. On the other hand, in the self-field formulation, there are no vacuum modes to be perturbed; rather, the presence of the wall modifies the self-energy of the atom in such a way that the required long-range, retarded potential results. The answer is precisely the same in either case.

This curious "duality" between the fluctuation and the radiation-reaction pictures pervades the literature. The first inkling of the connection came perhaps from Herbert Callen and Theodore Welton's famous fluctuation-dis-

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letters

sipation theorem of 1951.⁸ They showed that the two phenomena are inextricably linked—that the existence of one requires the existence of the other. Much later Jay R. Ackerhalt and coworkers,⁹ Israel R. Senitzky¹⁰ and Peter W. Milonni and coworkers¹¹—while working totally within the context of standard QED—were able to show that spontaneous emission can be interpreted as arising from vacuum fluctuations or from radiation reaction, dependent entirely on how the ordering of the field operators is chosen. By an appropriate choice, any linear combination of the two effects can be achieved. In 1982 J. Dalibard, J. Dupont-Roc and Claude Cohen-Tannoudji argued that the correct linear combination is $\frac{1}{2}$ (vacuum fluctuation) and $\frac{1}{2}$ (radiation reaction) to make the free-field operators and source-field operators separately Hermitian.¹²

Perhaps the point is that if one wants to observe the vacuum fluctuations one must use a charged particle—in which case the particle's self-field contributes to the measurement. In contradistinction, one can never observe the self-field of a charge in the absence of the all-permeating zero-point fluctuations. Any separation of these two effects can take place only in our minds, and then it's philosophy—not physics.

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2/87

SPRUCH REPLIES: It has long been clear

(see the literature cited by Jonathan P. Dowling) that the concept of electromagnetic vacuum fluctuations is not the only viewpoint one can adopt in explaining retarded interactions. However, space limitations—my article was rather long as it was—prevented me from discussing an alternative view based on radiation reactions. That was much to my regret, since each viewpoint brings its own insights, insights that are particularly valuable now that Casimir effects are no longer restricted to atomic phenomena, having recently become of great interest in a number of other areas of physics. I am therefore delighted to have this latter point of view not only presented but presented so well.

I do have a slight objection to the last sentence of the letter. Though the author in no way implies any such thing, one could conceivably come away with the impression that I am philosophically oriented.

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7/87

Peer review and the FEL

The news story on the Strategic Defense Initiative in the January 1987 issue (page 47) presents a useful survey of current thinking in and out of government. One point in particular, however, is worth examining in more detail, namely that "the centerpiece of the program is the free-electron laser."

While there has been considerable discussion in PHYSICS TODAY about the desirability of the proposed Superconducting Super Collider in the light of severe budget constraints, similar scientific and public attention has not been focused on such expensive defense-related projects as the proposed multimile-long FEL facility for which site selection is under way.¹ It is anticipated that this project will cost on the order of \$3 billion.

The lack of peer review in the SDI Organization makes this demonstration program suspect. Independent of the very persuasive political, strategic and purely technological arguments against Star Wars, the decision to go ahead with a giant FEL facility is questionable.

The leading contenders for the prototype FEL space weapon are a Los Alamos group² and a Lawrence Livermore Lab facility.³ The former uses an rf linac to inject very short electron beam pulses into an optical cavity containing a wiggler magnetic field. Published results for the coherent output radiation show that the efficiency

continued on page 110



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