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

1 L. C. Biedenharn, Found. Phys. 13, 13 (1983).

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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-