Questions on the Quark Model: Panel Discussion

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In atomic, nuclear, and particle physics, one often deals with complicated potentials where the analytic solution to the bound state wave functions is not known. One general approach to this problem is to diagonalize the Hamiltonian in a finite, i.e., truncated, model space. While this method is generally very good in determining the low-lying energy levels, it is not without problems. For example, an operator that is known to commute with the Hamiltonian may not, in the model space, actually commute with the Hamiltonian. To deal with this problem, one tries to find effective operators in the model space that do satisfy the properties of the operators in the untruncated space.

A specific example of this problem is current conservation in the quark model, which was discussed at length at this workshop [1, 2]. One problem is that due to truncation of the space, the current is not conserved, i.e., \( \partial_{\mu} j^\mu \neq 0 \). Of course, one can always define a new current that is conserved, e.g., in momentum space,

\[
\tilde{j}^\mu = j^\mu - \frac{K \cdot j}{K^2} K^\mu,
\]

where \( j \) is the current and \( K \) is the photon four-momentum. However, this is not unique, which is not satisfactory since we want a microscopic model to give us an unique answer.

The degree of violation of current conservation in the quark model has been investigated by Bourdeau and Mukhopadhyay [3] and Drechsel and Giannini [4]. The general conclusion from these works is that there is a severe violation of current conservation, making predictions of small quantities, such as the \( N = \Delta(1232) \ E2 \) transition, unreliable. Indeed, Buchmann [2] presented evidence at this workshop that two-body currents, neglected in most quark model calculations of \( E2 \), actually dominate this transition amplitude.

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Close and Li [5] have proposed general effective operators to deal with this problem. Capstick and collaborators [6] have partially implemented these operators in their relativised quark model, but even Capstick admitted at this workshop that $E2$ calculations are still not very accurate. The problem in these calculations is not just the truncation of the space. In fact, compared to the earliest quark model calculations, the model spaces now being used are huge. The additional problem one is now encountering is what to use for the electromagnetic transition operators. In other words, how do we consistently relativize these operators? In atomic physics, this may be done by means of a Foldy-Wouthuysen (FW) transformation. Unfortunately, in quark model calculations the FW series converges very slowly, if at all [7]. A specific example of this may be found in the classic text book by Close [8], where, in the FW scheme, the magnetic interaction energy turns out to be nearly as large as the Coulomb interaction energy.

In conclusion, this is a difficult problem that deserves serious attention. the good news is that it is being taken seriously as was evidenced by the presentations of Demetriou [1] and Buchmann [2] at this workshop.

We thank the participants of this panel for many stimulating discussions.

References

1. See P. Demetriou’s contribution to this workshop.


