DOE/ER/40264--5

FINAL FINAL REPORT Grant number DE FGO2 86ER40264/5-25351
April 16, 1997

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Introduction

Since what follows is the final final report that the author will ever submit to DOE, it seems appropriate to him that it should be a long-term review, since he has received support from DOE and its predecessor agencies since 1957. The report also contains some material from the earliest years of his career. The next three sections contain an account of what the author thinks he has accomplished in terms of research, of graduate students trained, and post-doctoral fellows trained. There follows a bibliography, consistently referred to in the previous sections and a C V. for completeness.

Review of research accomplishments

This section contains a brief summary of the major research accomplishments of the writer during the period since his Ph. D. (1950). Collaborators, who have often played an essential role, are listed in the bibliography.

1. *Quantum electrodynamics.* Classic papers on the hyperfine structure and Lamb shift in Hydrogen as well as the first treatment of positronium by means of the Bethe-Salpeter equation, items 2-6 of the bibliography. Later directed a thesis by Zemach on nuclear size corrections for the hyperfine structure problem, item 19.

2. *Nuclear forces.* Items 7-14, 32, 33, 37, 48, 132, 137. Much of the detailed calculation was premature in the light of present knowledge, but contributions of permanent value include the general procedure for transforming the Bethe-Salpeter (BS) equation to a single-time equation, items 8, 13, and 132, and ideas about the relation between nuclear forces and pion-nucleon scattering, items 14 and 33.

3. *Meson pair theory.* A classic paper on the treatment of an exactly soluble model in field theory, item 16, which among other firsts contains the first application to field theory problems of the theory of singular integral equations, later applied to the theory of dispersion relations by Omnes and carrying his name.

4. *Low energy theorems.* Item 17. One of the first papers to apply methods of functional differentiation with respect to external sources to the

study of S-matrix elements in field theory.

5. *Covariant theory of scattering, including bound states.* Items 20, 21, and 26.

6. *Application of Green's function methods to the many-body problem.* Pioneering work on normal fermi liquids, items 34, 35, 44, 49, 50, 60, 61; contributions to the theory of superfluid systems, items 55, 56, 57, and 59; other papers, 40 and 54.

7. *Potential scattering.* Item 36, first proof of the convergence of the Born scattering series in three dimensions; a proof of the dispersion relation for potential scattering, item 38, and a proof of the Mandelstam representation for potential scattering, item 42; related papers, items 45, 46.

8. *Broken symmetry in field theory.* Items 63, 64, 69, and 70. The last item, in particular, augers the discovery of the Higgs mechanism. Indeed, in an invited paper, delivered in the fall of 1963 at a Chicago meeting of APS, A. Klein, Bull. Am. Phys. Soc. **8**, 536 (1963), a formal theory of the Higgs mechanism was outlined.

9. *Phonons in liquid Helium.* A fundamental paper, item 71, and the last paper I wrote on the application of Green's function methods to the many body problem.

10. *Kerman-Klein method.* items 58, 62, 65, 66, 68, 72-80, 82-89, plus many later papers, but most particularly 93 and 182, which are reviews, and 107, which was our last effort, until recently to apply the original form of the method in a numerical application. As it developed this method has numerous aspects. It was originally invented as an equation of motion method for restoring the broken symmetry of the mean field field solutions encountered in nuclear physics. Subsequently it was recognized as a general method of applying Heisenberg's matrix mechanics to a wide class of quantum-mechanical and field-theoretical problems. It also implied a new method of treating collective coordinates with a phenomenological aspect, that could be studied on its own terms. Methods for expanding about well-determined mean field solutions were established, but the numerical treatment of transitional

situations is still in its infancy. Recent promising applications of this method are discussed near the end of this chapter.

11. *Equations of motion and Lie algebras.* This approach is an alternative method to implement the ideas of the KK method, that for many applications may be more practical than the original formulation. Thus, the original method combines the equations of motion with the fermion anticommutation algebra. Matrix elements of single fermion operators couple even and odd systems, which must both be treated selfconsistently. By replacing the anticommutation rules by a Lie algebra of pair and multipole operators, the study of even and odd systems could be divorced , thus simplifying the theory and the applications. Several methods of exploiting the constraints imposed by the Pauli principle were developed; exactly soluble models were studied to test methods of calculation; new variational principles were successfully tested; finally some applications to realistic nuclear systems were carried out. Despite this effort, the subject remains in its infancy. Items 92, 95-97, 100, 108,111,112,114, 116-120, 124, 128, 130, 134, 144, 145, 148, 153-156, 158, 159, 164.

12. *Boson mappings of shell model algebras, early work.* The Holstein-Primakoff mapping of SU(2) was reinvented and introduced into nuclear physics. One of the first connections in the literature between the TDHF method and boson mappings was made. The failure of convergence of the original Marumori mapping was explained, and a method of curing this disease was developed. The 'transition operator boson' was invented. Items 90, 91, 98, 101, 106, 110, 111, 115, 169.

13. *VMI phenomenology.* Early papers extended the variable moment of inertia method to multiband situations and explained how such a phenomenology could emerge from a microscopic theory. Later work produced a series of generalizations applicable to non-rotational nuclei, including the VMI as a special case, and a successful systematic analysis of all existing data was carried out. Items 102, 104, 105, 163, 186, 187.

14. *Stability of the vacuum in the presence of strong Coulomb fields.* We gave an explanation for the 'diving into the vacuum', i.e., the predicted

phenomenon of spontaneous production of positrons in the neighborhood of supercritically charged atomic nuclei, as a property of the Dirac equation, studied the corresponding theory for the Klein-Gordon equation and co-authored a review of the entire subject. Items 122, 125, 129, 133, 135, 139, 150, 161.

15. *Quantum theory of solitons.* The Kerman-Klein method was applied to the study of a number of field theories in one spatial dimension, each giving rise in the mean field approximation to soliton solutions. It was successfully shown how to restore the broken symmetry and how to make a systematic expansion about the soliton limit in order to include quantum corrections. This work also stimulated work on the quantal significance of solutions of the TDHF equations for heavy ion scattering, Items 138, 140, 141, 142, 149, and 152.

16. *WKB approximation.* Derivation of the standard WKB from Heisenberg matrix mechanics, items 147, 157, and the use of boson mappings for semi-classical quantization of systems described by Hamiltonians belonging to the enveloping algebra of a Lie algebra, item 170. Recent work that returned to item 157, whose fundamental significance was not quiote realized at the time of writing, will be discussed below.

17. *Interacting boson model.* A complete method was described for establishing the relation between the IBM and the Bohr-Mottelson theory. A new variational principle for boson Hamiltonians was developed to serve as a basis for the microscopic derivation of the IBM. This work stimulated the new efforts in boson mappings described below. Items 167, 168, 175, 177.

18. *Invariance principle of the Schrodinger equation.* This work, which is still "crying" for further development, outlines a complete theory of collective motion, based on an idea that can be characterized as a quantum generalization of the concept of coherent state. Items 174, 185 (see also 111).

19. *Kerman-Klein revisited.* Item 191. A revised theoretical formulation with some new results and insights. Also awaits further development.

20. *New ideas in TDHF.* Items 207, 208, 214. The main thrust here is the suggestion of a method for using the existing TDHF software to obtain quantum information from the study of heavy ion collisions. We are also seeking a connection with the ideas of Balian and Veneroni for extracting two-particle correlations from TDHF calculations.

21. *Bosons, more recent work.* Stimulated by the work on IBM, we have developed two new methods for boson mapping. One involves a modification of the standard perturbative study of the commutation relations, and the second a systematic use of the easily obtained Dyson mapping followed by a unitarization procedure. The latter method was developed independently (and generalized) by a number of other authors (Rowe *et al*, Deenen and Quesne, Moshinsky *et al*) and in the hands of the first set of authors, especially, under the rubric 'Vector Coherent State Theory', has led to important new results in group representation theory. We have authored, in collaboration with E. Marshalek, item 238, a massive review article on boson mapping of Lie algebras with applications to nuclear physics. In part as an outgrowth of the review we have been able to make a futher contribution to the development of the Vector Coherent-State method, items 218, 226, 230, and especially 235.

22. *Large amplitude collective motion.* This is the project on which the writer has been most heavily engaged for the past decade and a half. We have described two different quantum foundations for a classical theory of large amplitude collective motion in the adiabatic limit, items 183, 184, 188. The remaining work has involved a systematic study of the classical theory that not only subsumes almost all previous work, but also contains a completely new pathway to applications. We have reviewed the theory, carried out several elementary applications, and begun our main program of application to realistic nuclear problems. Items 190, 194, 195, 197, 200, 203, 206, 210-212, 215, 219, 220, 221, 224, 227-229, 231, 236, 237. In connection with this general program, we have also revisited and extended the theory of quantum corrections to collective motion. Items 239, 241, 244.

23. *New theory of effective interactions in the particle-hole channel.* Items 193, 221, 222. A theory in the course of development that contains

novel phenomenological as well as microscopic aspects. The aim of this work is to include both long and short range correlations in a unified formalism that utilizes mean field approximations of practical nuclear theory as a starting point.

24. *Quantum-classical correspondence.* We have shown that the method of Heisenberg matrix mechanics in the guise of the KK method provides new results and insights into the quantum-classical correspondence and the problem of semi-classical quantization of regular non-separable systems. Items 259, 260, 267, 268. The question of whether such methods can be applied to chaotic systems remains unanswered.

25. *Possible resonances in electron-positron scattering.* We applied an equation of motion method to the derivation of a relativistic two-particle system. Stimulated by experiments that have now been withdrawn, we studied solutions for electon-positron scattering at low energies, looking for, but not expecting and not finding resonances. Items 240, 243, 246.

26. *Skyrmion theory.* The Kerman-Klein theory was applied to the problem of quantizing the Skyrmion model and to thus restoring the broken symmetry manifest in the classical solutions. Items 242,248.

27. *Further work on large amplitude collective motion at zero temperature.* We have begun a program for the reevaluation of the fundamentals of this theory, in particular the way that Berry phase effects enter and how to generalize from the adiabatic approxiamtion to the diabatic approximation. The latter work is still in the course of development. Fully realistic applications of this and earlier theory remain to be carried out. Items 251, 252, 255, 256.

28. *Semi-microscopic theory of odd nuclei* We have resuscitated a semi-microscopic version of the original Kerman-Klein method that is, nevertheless, more microscopic than competing core-particle models. This model has been applied successfully to a number of cases. Items 258, 264, 265, 266. We then turned to some more geneal questions associated with this development. We studied the relationship of our method to the conventional strong-coupling core-particle coupling model, a limiting case of our theory. item 269. Most exciting to us have been the

latest developments. First we propôsed what we believe is the basically correct explanation, of a long-standing problem in this field, the so-called attenuation of the Coriolis coupling. Our solution points to a missing dipole interaction in the conventional Hamiltonian applied to this type of problem, item 270. Finally we have achieved a long-sought breakthrough of turning this model into a fully microscopic one, item 271.

29. *Large amplitude motion at finite excitation energy.* In the first work in this area, we have developed a theory and carried out a first application for the exchange of energy between collective ane non-collective degrees of freedom in the self-consistent theory of large amplitude collective motion. We have particularly dealt with the limit in which the flow of energy between the subsystems is inidirectional and can be described by classial friction parameters. A microscopic theory of these parameters has been provided. Items 273, 274.

30. *Connection between density functional theory and the KK method.* The density functional theory of W. Kohn and collaborators has had a tremendous impact in the fields of atomic, molecular, and condensed-matter physics. Nevertheless, it has had only limited success in the treatment of excited states, for which the KK method is particularly suited. This has suggested a study of the possibility of adding our ideas to the density-functional field. This work is in a very early stage, item 275.

Graduate students

In this section we list and describe briefly, in so far as we are aware of the facts, the accomplishments and present whereabouts of the writer's graduate students. The topics of thesis research are identified by publications in the writer's bibliography, except where publication was not joint.

1. Bruce H. McCormick. Ph.D., Harvard U., 1955. Thesis: see (16) and (33). After an initial stint as research associate at Brookhaven Nat. Lab., worked with L. Alvarez and is mentioned by latter in his Nobel address as inventor of an automatic scanning principle. Has been professor in depts. of applied math and computing at the U. of Illinois and is now professor of electrical engineering at Texas A. and M.

2. Charles Zemach. Ph.D., Harvard U., 1955. Thesis: see (19), which is a preliminary publication. Full publication made independently later. Has been professor of physics at the U. of Cal., Berkeley, science advisor to the state dept., and is now at Los Alamos. Spent the academic year 56-57 working with the writer at the U. of Pa., see section on research associates.

3. Jeremy Bernstein. Ph.D., Harvard U., 1955. Thesis: see (18). After an early career in research, mainly in weak interactions, now a distinguished science writer and prof. of physics (emeritus) at Stevens Inst. of Tech.

4. Richard E. Norton. Ph.D., U. of Pa., 1958. Thesis: see (27) and (28). Prof. of Physics at UCLA. Research in field theory and statistical mechanics.

5. L. Donald Pearlstein. Ph.D., U. of Pa., 1960. Thesis: see (43) and (47). Has spent most of his career doing research in plasma theory, collaborating with, among others, Marshall Rosenbluth. Now at the Lawrence Livermore Lab.

6. Malcolm Younger. Ph.D., U. of Pa., 1960. Thesis: see (51). Present whereabouts and activities unknown.

7. T. Kobayashi. Research: see (31). Received job offer and returned to Japan without his Ph.D. Now professor at Tokyo Metropolitan U.

8. Narkis Tzoar. Ph.D., U. of Pa., 1961. Thesis and research: see (30), (37), and especially (54). Now professor at CUNY, working in the theory of condensed matter.

9. R. Aaron. Research: see (45). Did a thesis with R. D. Amado. Now professor of physics at Northeastern U.

10. Benjamin W. Lee. Ph.D., U. of Pa., 1961. Research: see (39) and (41). Thesis: Mandlestam Representation for K-Nucleon System, was an 'independent ' research project. Distinguished particle theorist who headed the theory dept. at Fermilab at the time of his tragic death in an automobile accident more than a decade ago.

11. J. Iizuka. Ph.D., U. of Pa., 1961. Thesis: see (52) and (53). Well-known quark theorist and professor of physics at Nagoya U.

12. G. Do Dang. Ph. D., U. of Paris, 1964. Research: see (62) and (68). Long-time collaborator and currently *directeur de recherche*, a position in the CNRS, at the U. of Paris, Orsay.

13. L. Celenza. Ph.D., U. of Pa., 1966. Thesis: see (75) and (81). Now professor of physics at Brooklyn College of CUNY, where he has been engaged in a long-term collaboration with C. Shakin.

14. Robert E. Johnson. Ph.D., U. of Pa., 1968. Thesis: see (79), (87), (88), and (91). The last part of his thesis, on the derivation of the Bohr-Mottelson theory from the Kerman-Klein equations never published. Now professor at the Royal Military College in Ontario.

15. Gerard G. Dreiss. Ph.D., U. of Pa., 1969. Thesis: see (84), (85), (94), (97), and especially (107). Was associate editor of Phys. Rev. C before his tragic death in an automobile accident a few years ago.

16. Tappan K. Das. Ph.D., U. of Pa., 1970. Thesis: see (99), (102), and (105). Also unpublished part presaging the IBM-1 model. Now holds professorship at the U. of Calcutta.

17. Sho Yung Li. Ph.D., U. of Pa., 1971. Thesis: see (98), (101), (106), and (110). At last contact was group leader at the research labs of Xerox Corp.

18. Franz R. Krejs. Ph.D., U. of Pa., 1972. Thesis: see (108), (118), and (120). Currently president of a venture capital firm in Vienna.

19. Michel Vallieres. Ph.D., U. of Pa., 1973. Thesis: see (113) and (117). There was also an independent publication with R. M. Dreizler. Now professor of physics and chairman of the physics department at Drexel U.

20. Pranab K. Chattopadhyay. Ph.D., U. of Pa., 1975. Thesis: see (114), (118), (130), and (134). Now holds professorship at Mahari Dayanand U. in India.

21. Ching Teh Li. Ph.D., U. of Pa., 1978. Thesis: see (136), (144), (145), (155), and (156). Currently professor. at National Taiwan University in Taipei.

22. Moyez J. Vassanji. Ph.D., U. of Pa., 1978. Thesis: see (144), (145), (148), (153), (154), and (158). Until recently in a research position at the U. of Toronto associated with David Rowe. Has published prize-winning novels and short stories and has definitely turned to full-time writing.

23. Tom Cohen. Ph.D., U. of Pa., 1985. Thesis: see (176), (178), and (179), but bulk of thesis was independent research. Now associate professor at the U. of Maryland.

24. Dennis Bonatsos. Ph.D., U. of Pa., 1985. Thesis: see (186), (187), (189), (192), (196), and (198). Currently in a permanent research position at the institute "Democritus" in Athens.

25. David Cebula. Ph. D. , U. of Pa., 1992. Thesis: see (242), (248). Currently employed at the Lincoln Laboratory.

26. Pavlos Protopapas. Ph. D. , U. of Pa., 1996. Thesis: see (258), (264), (265), and (266).

Post-doctoral fellows

In this section we list those persons who have collaborated with the writer as part of their immediate postdoctoral experiences and also refer, through the writer's bibliography, to the research accomplished. Most, though not all, of these individuals were hired as research associates by the writer. There is some overlap with the list of Ph.D. students in that several of the latter did return to do further work with the author. If no current address is given, the entry is thus identified as a former student whose whereabouts has been documented in the section on graduate students.

1. Charles Zemach (1956-1957). Research: (26), (36), and (38). The latter two papers are classic papers on potential scattering.

2. R. E. Prange (1958-1960). Research: (33), (34), and independant work. Items mentioned are classic papers on normal fermi liquids. Prange is now a distinguished condensed matter theorist and professor at the U. of Maryland.

3. D. Fivel (1960-1962). Research: (46). Now professor at the U. of Maryland.

4. R. Raphael (1959-1960). Research: (37) and (48). Now professor at U. of Alabama, Huntsville.

5. R. M. Dreizler (1964-1972). Research: (73), (74), (76), (80), (81), (83-87), (89-92), (95), (96), (98-105), (107), (108), (110), (113), (115), (117). Dreizler was the first research associate who worked with me on the nuclear many-body problem. Now professor at Frankfurt U, a leader in the field of atomic theory.

6. G. Do Dang (1966-1969). Research: (77), (78), (80), (82-86), (89), (92). Do Dang produced the first self-consistent solutions of the Kerman-Klein equations.

7. Chi Shiang Wu (1966-1967). Research: (80), (83-86), (89). Now professor at the U. of Victoria in British Columbia.

8. S. C. Pang (1969-1971). Research: (90), (94), (112). At last contact, was engaged in the field of medical physics in the Boston area.

9. Carlos Dasso (1972-1974). Research: (116), (118), (119), (121), (123), (128). Now a widely known nuclear theorist who is assoc. professsor at Nordita.

10. Lewis Fulcher (1972-1974). Research: (122), (129), (150), (161). This work, as well as some of the papers with Rafelski concerned the problem of spontaneous decay of the vaccum in strong Coulomb fields. Now professor at Bowling Green U.

11. J. Rafelski (1974-1975). Research: (125-127), (131), (133), (135), (139), (146), (150), (161). Now professor at the U. of Arizona.

12. T.-S. H. Lee (1974-1975). Research: (132), (137). Work on the two-nucleon problem. Now a member of the physics dept. at Argonne Nat. Lab.

13. F. Krejs (1975-1978). Research: (136), (138), (140), (141), (144), (152). This work, as well as the paper with Weldon is concerned with the quantum theory of solitons.

14. Arthur T. Weldon (1978-1979). Research: (149). Now assoc. professor at West Va. U.

15. C. T. Li (1979-1982). Research: (170), (172), (173), (175), (176), (179), (181).

16. M. Vallieres (1981-1982). Research: (167), (168), (172), (173), (175), (177), (179).

17. S. Umar (1985-1986). Research: (200), (207), (208), and (214). Now assoc. professor at Vanderbilt U.

18. A. S. Bulgac (1986-1988). Research: (210-212), (219), (220). Now asst. professor at the U. of Washington, Seattle.

19. N. R. Walet (1988-1993) Research: (228), (229), (231), (232), (235-237), (239-242), (244-246), (248, 249), (251, 252), (254-257). Now lecturer at Manchester Inst. of Technology, Manchester, England.

20. Wm. R. Greenberg. (1995-1996). Research: (259), (260), (267), and (268) Now engaged in financial work in NYC.

21. Pavlos Protopapas. (1996-1997). Research: (258), (264), (265),(266), (269), (270), (271), and (272). Currently employed as a research associate at the U. of Pa. in a project concerned with large scale rapid data processing.

Publications of Abraham Klein: refereed journals, published lectures of invited papers at conferences, and lecture series from "schools"

1. The Coupling of a Dirac Field to a Kemmer Field. Phys. Rev. **82**, 639 (1951).

2. Electrodynamic Displacement of Atomic Energy Levels. (with Robert Karplus and Julian Schwinger) Phys. Rev. **84**, 597 (1951).

3. Electrodynamic Displacement of Atomic Energy Levels. I. Hyperfine Structure. (with R. Karplus) Phys. Rev. **85**, 972 (1952).

4. Electrodynamic Displacement of Atomic Energy Levels. II. Lamb Shift. (with R. Karplus and J. Schwinger) Phys. Rev. **86**, 288 (1952).

5. Electrodynamic Corrections to the Fine Structure of Positronium. (with R. Karplus) Phys. Rev. **86**, 257 (1952).

6. Electrodynamic Displacement of Atomic Energy Levels. III. The Hyperfine Structure of Positronium. (with R. Karplus) Phys. Rev. **87**, 848 (1952).

7. Symmetric Pseudoscalar Theory of Nuclear Forces. Phys. Rev. **89**, 1158 (1953).

8. The Tamm-Dancoff Formalism and the Symmetric Pseudoscalar Theory of Nuclear Forces, Phys. Rev. **90**, 1101 (1953).

9. Convergence of the Adiabatic Nuclear Potential. Phys. Rev. **91**, 740 (1953).

10. Convergence of the Adiabatic Nuclear Potential II. Phys. Rev. **92**, 1017 (1953).

11. The Construction of Potentials in Quantum Field Theory. Phys. Rev. **91**, 1285 (1953).

12. Configuration Space Methods for the Construction of Potentials. Phys. Rev. **94**, 195 (1954).

13. Single-Time Formalisms from Covariant Equations. Phys. Rev. **94**, 1052 (1954).

14. Suppression of Pair Coupling in Nuclear Forces. Phys. Rev. **95**, 1061 (1954).

15. New Tamm-Dancoff Formalism. Phys. Rev. **95**, 1676 (1954).

16. Meson Pair Theory. (with Bruce H. McCormick). Phys. Rev. **98**, 1428 (1955).

17. Low-Energy Theorems for Renormalizable Field Theories. Phys. Rev. **99**, 998 (1955).

18. Electromagnetic Properties of the Deuteron. I. Charge Density and Quadrupole Moment. (with Jeremy Bernstein) Phys. Rev. **99**, 966 (1955).

19. Spatial Extension of the Proton Magnetic Moment from the Hyperfine Structure of Hydrogen. (with W. M. Moellering, F. E. Low, and A. C. Zemach), Phys. Rev. **100**, 441 (1955).

20. Scattering Matrix in the Heisenberg Representation for a System with Bound States. Prog. Theoret. Phys. **14**, No. 6 (1955).

21. Derivation of Low Scattering Formalism. Phys. Rev. **102**, 913 (1956).

22. Dispersion Relations for Fixed-Source Meson Theories. Phys. Rev. **104**, 1131 (1956).

23. Dispersion Relations for Fixed-Source Meson Theories: Effective-Range Relations. Phys. Rev. **104**, 1136 (1956).

24. Construction of the Adiabatic Nuclear Potential: Formalism. Phys. Rev. **104**, 1747 (1956).

25. Transition Amplitudes for Photoproduction of Mesons from Nucleons and Photodisintegration of the Deuteron. (with L. Donald Pearlstein). Phys. Rev. **107**, 836 (1957).

26. Many-Body Problem in Quantum Field Theory.(with Charles Zemach) Phys. Rev. **108**, 126 (1957).

27. Complete Set of Dispersion Relations for a Class of Fixed-Source Meson Theories. (with R. E. Norton). Phys. Rev. **109**, 584 (1958).

28. Significance of the Redundant Solutions of the Low-Wick Equation. (with R. E. Norton). Phys. Rev. **109**, 991 (1958).

29. Phenomenological Analysis of μ Decay. (with S. A. Bludman) Phys. Rev. **109**, 550 (1958).

30. Inner Bremsstrahlung in μ-Meson Decay. (with N. Tzoar) Nuovo Cimento **8**, 482 (1958).

31. Remarks on a Model for S-Wave Meson-Nucleon Scattering. (with T. Kobayashi) Nuovo Cimento **8**, 850 (1958).

32. On the Concept of Potential in Quantum Field Theory. Prog. Theor. Phys. **20**, 257 (1958).

33. Derivation of the Two-Nucleon Potential. (with B. H. McCormick) Prog. Theor. Phys. **20**, 876 (1958).

34. Perturbation Theory for an Infinite Medium of Fermions. (with Richard Prange) Phys. Rev. **112**, 994 (1958).

35. Generalized Reaction Matrix Approach to the Theory of the Infinite Medium of Fermions. (with Richard Prange) Phys. Rev. **112**, 1008 (1958).

36. The Born Expansion in Non-Relativistic Quantum Theory. (with C. Zemach) Nuovo Cimento **10**, 1078 (1958).

37. Meson Theoretical Origin of the Spin-Orbit Coupling between Two Nucleons. (with N. Tzoar and R. Raphael) Phys. Rev. Lett. **2**, 433 (1959).

38. Analytic Properties of the Amplitude for the Scattering of a Particle by a Central Potential. (with C. Zemach) Annals of Physics **7**, 440 (1959).

39. Application of the Chew-Low Formalism of Multi-Channel Reactions. (with B. W. Lee) Nuovo Cimento **13**, 891 (1959).

40. Many-Particle Approach to the One-Electron Problem in Insulators and Semiconductors. Phys. Rev. **115**, 1136 (1959).

41. A Novel Dispersion Relation for Potential Scattering. (with B. W. Lee) Nuovo Cimento **14**, 856 (1959).

42. Mandelstem Representation for Potential Scattering. J. Math. Phys. **1**, 41 (1960).

43. Theory of the Photodisintegration of the Deuteron. (with L. D. Pearlstein) Phys. Rev. **118**, 193 (1960).

44. Linked Cluster Expansion Applicable to Nonspherical Situations. Phys. Rev. Lett. **4**, 601 (1960).

45. Convergence of the Born Expansion. (with R. Aaron) J. Math. Phys. **1**, 131 (1960).

46. On the Analytic Properties of Partial Wave Amplitudes in Yukawa Potential Scattering. (with D. Fivel) J. Math. Phys. **1**, 131 (1960).

47. Theory of Photo-Disintegration of the Deuteron. (with L. D. Pearlstein) *Nuclear Forces and the Few Nucleon Problem*, ed. by T. C. Griffith and E. A. Power (Pergamon Press, Vol. **1**, p. 329-340 (1960).

48. Meson-Theoretical Calculation of the Spin-Orbit Coupling between Two Nucleons. (with N. Tzoar and R. Raphael) *Nuclear Forces and the Few Nucleon Problem*, ed. by T. C. Griffith and E. A. Power (Pergamon Press, Vol. **1**, p. 143-152 (1960).

49. Perturbation Theory for an Infinite Medium of Fermions. II. Phys. Rev. **121**, 950 (1961).

50. Perturbation Theory for an Infinite Medium of Fermions. III. Derivation of the Landau Theory of Fermi Liquids. Phys. Rev. **121**, 957 (1961).

51. On the Validity of the Static Approximation for the Evaluation of the Two-Nucleon Potential. (with Malcolm Younger) Journ. of the Franklin Institute Vol. **271**, No. 6 (1961).

52. Theory of Single Pion Production in Proton-Proton Collisions. (with J. Iizuka) Phys. Rev.**123**, 669 (1961).

53. Dispersion Relations for Virtual Pion-Nucleon Scattering. (with J. Iizuka) Prog. Theor. Phys. **25**, 1017 (1961).

54. Absorption of Electromagnetic Radiation by an Electron Gas. (with N. Tzoar) Phys. Rev. **124**, 1297 (1961).

55. On the Exact Solution of the BCS Reduced Hamiltonian and a Systematic Perturbation Theory Constructed Therefrom. Proceedings Midwest Conf. on Theoretical Physics, 1961.

56. Theory of Fermion Systems with Attractive Interactions: Exact Solution of the BCS Reduced Hamiltonian. Nuovo Cimento **24**, 788 (1962).

57. The Description of Superfluid Fermi Systems with Anisotropic Features. Nuovo Cimento **23**, 919 (1962).

58. The Description of Rotating Nuclei. (with A. K. Kerman) Physics Letters **1**, 185 (1962).

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272. Kerman-Klein method for Nuclear Structure: Accomplishments and Opportunities (with P. Protopapas), Proceedings Drexel Symposium on the Shell Model (1996), to be published.

273. Model of a self-consistent theory of large amplitude collective motion at finite excitation energy (with G. Do Dang and P. G. Reinhard), in preparation.

274. Self-consistent theory of large amplitude collective motion at finite excitation energy (with G. Do Dang and P. G. Reinhard), in preparation.

275. Variational principle for ground state energy as a functional of the one-particle density matrix: a generalization of Hartree-Fock theory (with R. M. Dreizler), in preparation.

Curriculum vitae of Abraham Klein

Born:	[redacted]
Graduated:	B.A. Brooklyn College, January, 1947
Higher Degrees:	M.A., Harvard University, June, 1948
	Ph.D., Harvard University, June, 1950
Married (1950),	2 children

Societies

- American Physical Society (Fellow)
- AAUP
- AAPT

Fellowships and Honors

1. Brooklyn College, Summa Cum Laude, 1st in class of 1500.
2. AEC Pre-Doctoral Fellow, Harvard Univ. (1949-1950).
3. Sigma Xi (1950).
4. Junior Fellow, Society of Fellows, Harvard Univ. (1952-1955).
5. National Science Foundation Senior Postdoctoral Fellow (1961-62).
6. Alfred P. Sloan Foundation Fellow (1961-1963).
7. Distinguished Alumnus Award, Brooklyn College (1966).
8. J. S. Guggenheim Fellowship (1975).
9. Alexander von Humboldt Foundation Senior Scientist Award (1987).
10. Honorary doctorate, Frankfurt U. (1995).
11. Humboldt Award extension (1995).

Services

1. Associate Editor, Physical Review (1965-68).
2. Program Committee, Division of Nuclear Physics (1973-75).
3. Associate Chairman for Graduate Education, Physics Dept., U. of Pa. (1980-1983).
4. Co-chairman, Organizing Committee 13th Eastern Theory Conference at U. of Pa. (1974).
5. Organizing Committee 15th Eastern Theory Conference at Univ. of Georgia (1976).
6. Organizing Committee, International Conference on Band Structure and Nuclear Dynamics, New Orleans (1980).
7. Scientific Committee, Int. School of Quantum Electrodynamics of Strong Fields, Lahnstein/Rhein (Germany) (1981).
8. International Advisory Committee, Conference on Nuclear Structure, Reactions and Symmetries - Dubrovnik, Yugoslavia (1986).
9. International Advisory Committee, 1st International Spring Seminar on Nuclear Physics, Sorrento, Italy (1986).
10. International Advisory Committee, Symposium on Modern Developments in Nuclear Physics, Novosobirsk, USSR (1987).
11. International Advisory Committee, 2nd International Spring Seminar On Nuclear Physics, Capri, Italy (1988).
12. International Advisory Committee, 3rd International Spring Seminar On Nuclear Physics, Ischia, Italy (1990).
13. Co-chair, Organizing Committee for Symposium to honor S. T. Belyaev, Drexel Umiversity, Philadelphia (1994).

Professional Record:

1.	Graduate Assistant, Harvard	1947-49
2.	AEC Pre-Doctoral Fellow, Harvard	1949-50
3.	Instructor, Harvard	1950-52
4.	Society of Fellows, Harvard	1952-55
5.	Research Associate, Harvard Nuclear Laboratory, Summer	1951
6.	Physicist, M.I.T., Summer reactor program (AEC), Summer	1952
7.	Visiting Physicist, U. of Rochester, Summer	1953
8.	Visiting Physicist, Brookhaven National Laboratory, Summer	1954
9.	Visiting Physicist, Brookhaven National Laboratory, Summer	1956
10.	Visiting Physicist, Radiation Laboratory, U. of California, Summer	1957
11.	Consultant, RIAS, Baltimore, Md., Summer	1959
12.	Consultant, Convair CT rporation	1960
13.	Lecturer, International Spring School of Theoretical Physics, Naples	1960
14.	Associate Professor of Physics, U. of P.	1955-58
15.	Professor of Physics, U. of P.	1958-1994
16.	N.S.F. Senior Postdoctoral Fellow, U. of Paris (Sabbatical Leave)	1961-62
17.	Alfred P. Sloan Foundation Fellow, U. of P.	1961-63
18.	Lecturer, Summer School of Theoretical Physics, U. of Paris	1962
19.	Visiting Physicist, Brookhaven National Laboratory, Summer	1963
20.	Visiting Professor, Faculty of Science, Univ. of Paris, Summer	1966
21.	Lecturer, Summer Inst. for Theor. Physics, Univ. of Colorado, Summer	1968
22.	Visiting Professor, Princeton Univ. (Sabbatical leave)	1968-69
23.	Visiting Professor, University of Frankfurt, June	1971
24.	Lecturer, Mont Tremblant International Summer School(Canada), August	1971
25.	Research Associate, Center for Theor. Physics, M.I.T. (Sabbatical Leave)	1975-76
26.	Summer Visitor, Ecole Normale Superieure, Paris - Summer	1976
27.	Visitor, Nordita and the Niels Bohr Institute, December	1980
28.	Special Foreign Visiting Professor, U. of Tsukuba, Japan, June-Aug.	1981
29.	Lecturer in School "Collective Bands in Nuclei", Erice, Sicily, March-April	1982
30.	Visiting Professor, Yale U., Fall term	1983

31.	Visiting Professor, Tech. U. Munich, January-March	1984
32.	Research Associate, CNRS (French National Research Organization) U. of Paris, April-August,	1984
33.	Lecturer in school "Symmetries and Semi-Classical Features of Nuclear Dynamics", Brasov, Romania, September	1986
34.	Visiting Professor, Frankfurt U., Fall term	1987
35.	Visiting Professor, Frankfurt U., Fall term	1988
36.	Visiting Professor, Stellenbosch U., March	1991
37.	Professor Emeritus, U. of Pennsyvania	1994-
38.	Distinguished Guest Professor, Drexel University	1994-
39.	Visiting Professor, U. of Paris XI, November	1994