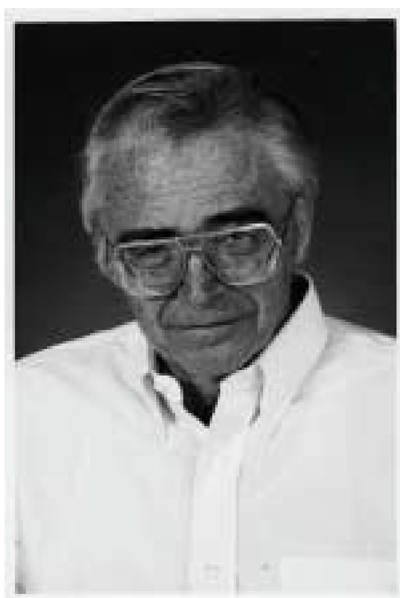
Richard Robb Hake

Curriculum Vitae (5/22/2000)

HAKE, Richard Robb, Emeritus Professor, Department of Physics , Indiana University, Bloomington, Indiana 47405; Internet <rrhake@earthlink.net>; < http://www.physics.indiana.edu/~hake/ > PHYSICS. Born: Colorado, July 15, 1927; married, three children. Education: B.S. (Physics Engineering) University of Colorado, 1950; M.S.(Physics), University of Illinois, 1951; Ph. D.(Physics), University of Illinois, 1955. United States Navy, 1945-46. Research Associate, University of Illinois, 1955-56. Senior Research Physicist, Atomics International Division of North American Aviation, 1956-62. Member of the Technical Staff, North American Rockwell Science Center, 1962-70. Consultant, Los Alamos Scientific Laboratories, 1970-73. Professor of Physics, Indiana University, 1970 -1995, Emeritus Professor, 1996 - present. Visiting Professor, University of California at San Diego, 1987-88. Visiting Scholar, Arizona State University, 1992. Oversight Committee, Conceptual Core Curriculum for Physics, 1994 - 1998. Editorial Board, *The Physics Teacher*, 1993 - 1996: Visiting Committee, NSF - Harvard University On-line Server for Educational Resources. Member: Pi Mu Epsilon, Sigma Pi Sigma, Sigma Tau, Tau Beta Pi, American Physical Society (Fellow), American Association of Physics Teachers, American Educational Research Association. Research Areas: Condensed matter and low-temperature physics, electronic properties, superconductivity, magnetism, cryogenics, science education.



Richard R. Hake

Dr. Hake has made significant contributions in the following areas:

1. Effects of Pressure and Isotopic Mass Variation in Superconductors

Dr. Hake and coworkers at the University of Illinois made precise measurements[2,3] of the isotope effect in the superconducting transition temperature of lead which showed that previous measurements were in error and that the actual isotope shift was as predicted on the basis of early electron-phonon interaction theories of Frohlich and Bardeen. They also measured[1] the pressure-induced transition-temperature shift of lead and discussed how this shift might be influenced by effects of pressure on both the electronic structure and the vibrational spectrum.

2. Electronic and Magnetic Properties of Transition Metals

Dr. Hake (with T.G. Berlincourt and D.H. Leslie) made the most detailed investigation[4-6] to date of the electronic transport properties of that class of bcc Ti-, Zr- and Hf-base transition metal alloys which display high and anomalously temperature and concentration dependent electrical resistivities of a type which are even today not fully understood. Hake (with Berlincourt, Leslie, and J.A. Cape)[10,11,20-22] discovered negative magnotresistance, resistance minima, Curie-Weiss susceptibility , and low-temperature specific heat anomalies in certain dilute hcp Ti-, Zr-, and Hf-base alloys, and emphasized the importance of such observations to theories of transition metals, magnetism, and superconductivity. This work was among the earliest studies of localized-moment phenomena in transition-metal-base alloys. Such studies were then extended to the spin-glass state in Zr-Mn alloys.[42] Dr. Hake was the first to provide definite evidence[5,6] in support of Pines's interpretation of the Matthias regularities for transition metal superconductors in terms of the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity. Hake's calorimetric measurements[5,6] gave the first evidence of the BCS-type energy gap in the electronic excitation spectrum of superconducting alloys, in agreement with P.W. Anderson's theory of "dirty" superconductors.

3. High-Field Superconductivity[52]

With T.G. Berlincourt and D.H. Leslie, Hake was the first to observe zero electrical resistance in magnetic fields as high as 30 kilogauss.[4] These workers also discovered[7,8,12-15,19,27] the technologically important high-field superconductivity in Ti-Nb alloys, the "peak effect" and rolling plane anisotropy in high-field alloys, and the correlation of critical current anisotropy with microstructure. They constructed[9] the first 45 and 60 kilogauss superconducting magnets and elucidated[12-15] the nature of upper critical fields in terms of the Ginzburg-Landau-Abrikosov-Gor'kov (GLAG) theory of type-II superconductors. (The popular terms "peak effect" and GLAG were both coined by Hake and Berlincourt.) Hake (with W.G. Brammer)[16-18] made the first detailed studies of the specific heat and related thermodynamic properties of reversible type-II superconductors.

Other pioneering work in high-field superconductivity includes (1) first observation of paramagnetically limited upper critical fields (with T.G. Berlincourt),[12,15] (2) first observation[24] of mixed-state magnetocaloric cooling (with L.T. Barnes), (3) derivation[17,18,30,32] of the thermodynamic interrelationships of magnetization with volume and pressure effects, as well as a unified discussion of the thermodynamic properties of type-I and type-II superconductors; (4) discovery[23,27,29] of the mixed-state Pauli paramagnetism in extreme type-II superconductors, and (with L.J. Barnes) the calorimetric verification[25,26] of a bulk, reversible, paramagnetic superconducting phase, (5) discussion[28] of upper critical field limits which consider the spin-flip mitigation of the Paul paramagnetic limitation; (6) first measurement[31] of the mixed-state Hall effect in an extreme type-two superconductor. The discovery and elucidation of high-field superoonductivity[12,15] in Ti-Nb (the present mainstay of technological high-field applications) and other alloys by Berlincourt and Hake in the 1960's has been historically described in "Type-II Superconductivity: Quest for Understanding," T.G. Berlincourt, in *H. Kamerlingh Onnes Symposium on the Origins of Applied Superconductivity, IEEE* **MAG-23**, 403 (1987); and in "Emergence of Nb-Ti as a Supermagnet Material," T.G. Berlincourt, *Cryogenics* **27**, 283 (1987).

4. Fluctuation Superconductivity

Dr. Hake was the first to observe[33-35] fluctuation superconductivity in bulk superconductors, isothermal quenching of superconductive fluctuations in bulk materials by high magnetic fields, and fluctuation-induced conductivity enhancement up to 3 T_c. With L.J. Barnes, W. Lue, A. Montgomery, and R.R. Hassing, Hake[37-39] obtained the first evidence for magnetic-ficld induced fluctuation dimensionality reduction, and for fluctuation superconductivity up to 140 kG [$H \leq 2H_{c2}$ (T = 0)].

5. Quantum Interference Effects (Weak Localization) in Bulk Disordered Metals

The first observations[40,41,43,45,49] of non-localized-magnetic-moment-related negative magnetoresistance and negative temperature coefficients of resistivity (both now know to be signatures of quantum interference effects) in highly disordered bulk crystalline an amorphous alloys at low temperatures were made by Hake and co-workers. They were apparently the first[43] to suggest the connection of these transport anomalies with weak electronic localization.

6. Superconductivity of Amorphous Metals

Hake and Karkut[46-48] provided the first evidence (contrary to Cal Tech and IBM work) that the temperature dependence of upper-critical fields of bulk amorphous alloys could be satisfactorily described by the standard dirty-limit Werthamer-Helfand-Hohenberg-Maki (WHHM) theory shown earlier[29] to be in fair accord with data for disordered crystalline alloys.

7. Uranium Compound and Very-High-Temperature Superconductors

During a half-year sabbatical (Spring, 1984) at the University of California - San Diego (UCSD), Hake worked with Brian Maple and his group to discover[50,51] four new U-compound superconductors (unfortunately, none of the heavy-fermion type). Then, in 1987-88 he collaborated[54-59,61-65] with this same group as a visiting professor at UCSD to investigate the new high-temperature superconductors. Among major accomplishments was the discovery[57] of the potential one megagauss superconductor $TmBa_2Cu_3O_{7-d}$ and the correlation[63,65] of the magnetic-field alignment direction of single-crystal-grain c-axes in $RBa_2Cu_3O_{7-d}$ (R = Nd, Sm, Tm, Yb) with the Stevens factor a_J of the crystalline electric field Hamiltonian.

8. Science Education

For the past fifteen years,[53,60,66-85] Dr. Hake has been engaged in a development, dissemination, and research program to improve introductory physics education at the local, state, and national levels.

The development has consisted in the instruction[53,60,67,68,70,71,77] of introductory physics courses with various innovations emphasizing interactive engagement of students, primarily Socratic Dialogue Inducing (SDI) laboratories. Nine SDI lab manuals on introductory mechanics, most of them with accompanying teacher's guides, and some with ancillary animation software[71] have now been developed. Much of this material is now available both in hard copy (available on request) and electronically: (a) the World Wide Web at < http://www.physics.indiana.edu/~sdi/ >, < http://www.physics.indiana.edu/~hake/ >, and < http://galileo.harvard.edu/ >, (b) floppy disks, and (c) the Fuller-Zollman "InfoMall." SDI labs have now been used successfully in several universities and high schools.[74-76]

The research has consisted of both qualitative and quantitative studies, intermixed in such a way as to be mutually supportive.[78,85] The former has involved the analysis of (a) videotaped individual interviews probing both cognitive and affective states of introductory physics students,[71,78] and (b) videotaped SDI lab sessions, including discussions both among students and between Socratic dialogists and students,[71,78] (c) comments and performance of students[53,60,73,76] and non-physical-science professors[60] enrolled in the introductory physics course, (d) case studies of courses in which nominally interactive-engagement methods were employed but minimal gains in conceptual understanding occurred.[76] The qualitative research has served to uncover many unsuspected barriers to learning, suggest new paths to physics understanding, and greatly improve the effectiveness of SDI labs.

The quantitative studies[53,60,71-76,78] have centered on student evaluations and careful prepost testing for both conceptual understanding and problem solving ability. Several years ago he completed a survey[74-77] of pre/post test data using the Halloun-Hestenes Mechanics Diagnostic MD test or more recent Force Concept Inventory FCI for 62 introductory physics courses enrolling a total number of students N = 6542. A consistent analysis over diverse student populations in high schools, colleges, and universities is obtained if a rough measure of the average effectiveness of a course in promoting conceptual understanding is taken to be the average normalized gain <g>.

The latter is defined as the ratio of the actual average gain (%<post> - %<pre>) to the maximum possible average gain (100 - %<pre>). Fourteen "traditional" (T) courses (N = 2084) which made little or no use of interactive-engagement (IE) methods achieved an average gain of $<g>_{T\text{-ave}} = 0.23 \pm 0.04$ (std dev). In sharp contrast, forty-eight courses (N = 4458) which made substantial use of IE methods achieved average gains of $<g>_{IE\text{-ave}} = 0.48 \pm 0.14$ (std dev), almost two standard deviations above that of the traditional courses. [Results consistent with these have recently been obtained by other physics-education research groups at the Univ. of Maryland, Univ. of Montana, Rennselaer, Tufts, North Carolina State Univ., and Hogskolan Dalarna (Sweden) - see citations in ref. 78.] Results for 30 (N = 3259) of the above 62 courses on the problem-solving Mechanics Baseline test of Hestenes-Wells suggest that IE strategies enhance problem-solving ability. IE strategies shown by the survey to be relatively effective are well documented in the literature,[74-78] can be melded together and modified so as to suit local circumstances, offer materials for their implementation,[76] and can successfully be brought to the masses (course enrollments greater than 200) in a cost-effective manner.[75] All of the above strongly suggests that (1) *the use of IE strategies can increase mechanics-course effectiveness well beyond that obtained with traditional methods,* (2) *physics instructors should give serious consideration to the gradual replacement of the traditional modes of mechanics instruction (and probably physics instruction generally) by IE methods.*

The survey indicates that the strenuous recent efforts to reform introductory physics instruction, enlightened by cognitive science and research in physics education, have shown very positive results in the classroom. However, history suggests the possibility that such efforts may have little lasting impact. This would be most unfortunate, considering the current imperative to (a) educate more effective science majors and science-trained professionals including teachers,[79] and (b) raise the appallingly low level of science literacy among the general population.[80] Progress towards these goals should increase our chances of solving the monumental science-intensive problems (economic, social, political, and environmental) that beset us, but major upgrading of physics education on a national scale will probably require:

(1) the interdisciplinary[81] cooperation of instructors, departments, institutions, and professional organizations [see, e.g., R.C. Hilborn, "Guest Comment: Revitalizing undergraduate physics - Who Needs It," *Am. J. Phys*. **65**(3), 175-177 (1997); "Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology," Advisory Committee to the NSF Directorate for Education and Human Services, 6/96, available at < http://www.nsf.gov/cgi-bin/getpub?nsf96139 >; “Shaping the Future, Volume II: Perspectives on Undergraduate Education in Science, Mathematics, Engineering, and Technology” at < http://www.nsf.gov/cgi-bin/getpub?nsf98128 >]

(2) long-term classroom use, feedback, assessment, research analysis, and redesign of interactive-engagement methods [K.G. Wilson and B. Daviss, *Redesigning Education* (Henry Holt, 1994)].

More recently Dr. Hake has:

(a) compiled a guide,[81,82] REDCUBE, that gives non-biologists (and even biologists) a point of entry into the vast literature and web resources relevant to REsearch, Development, and Change in Undergraduate Biology Education;

(b) discussed lessons from the physics-education-reform effort that might be significant for engineering,[83] environmental,[84] and general[85] education.

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(a) Biology Associations,
(b) Biology Teachers Web Sites,
(c) Scientific Societies and Projects (not confined to Biology),
(d) Higher Education,
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