In Memoriam: James K. Knowles 1931–2009[1]

James K. Knowles, one of the leading mathematical solid mechanicians of recent decades, passed away at his home on November 1, 2009. He was 78 years of age. He was on the faculty of the California Institute of Technology for 51 years, the last 13 of which were as emeritus.

Jim was admired and respected for the clarity, precision, and depth of his scholarship. He had a naturally unpretentious disposition. He was a teacher and mentor *par excellence*, who inspired generations of students. His infectious laughter put everyone at ease. Jim was warm and deeply caring, a treasured friend and colleague.

Jim was born in Cleveland, Ohio, on April 14, 1931, and grew up in Phoenix, Arizona. He entered Massachusetts Institute of Technology (MIT) in 1948, where he earned his SB (1952) and Ph.D. (1957), both in Mathematics.

In 1958, Jim joined the faculty of the California Institute of Technology (Caltech). He was appointed Full Professor in 1965 and the William J. Keenan Jr. Professor of Applied Mechanics in 1991.

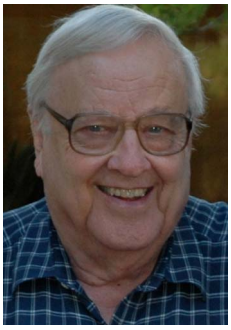
Jim believed that Caltech was academic utopia and had a deep affection for the institute. He had no desire to leave Caltech even on sabbatical leave, with the sole exception of a single sabbatical at MIT. This dedication to Caltech was recognized when he was made an Honorary Alumnus of the California Institute of Technology in 1991.

Jim was attracted to a variety of research topics in the mathematical theories of linear and nonlinear elasticity. These included the dynamics of discrete systems, material instability models of dissipation, the evolution of phase transitions in solids, wave propagation, loss of ellipticity and weak solutions, singular problems and conservation laws in nonlinear elasticity, analytical issues in fracture mechanics, questions pertaining to Saint-Venant's principle, nonlinear elastic oscillations, and shell theory. The final paper that Jim was to write was submitted for publication, 5 weeks prior to his death. It concerned conservation laws for one-dimensional lattices.

Some of his research contributed in fundamental ways to the foundations of solid mechanics, while others concerned specific problems of practical interest. At all times, Jim wanted to gain fundamental understanding and clarity into the question he was probing. He was an incisive thinker who was never hasty to say that he understood something.

Roger Fosdick, editor-in-chief of the *Journal of Elasticity*, says that "He set an example of scholarship and fundamental thought, both broad and deep, that challenged students as well as researchers. He was highly inquisitive, deeply thoughtful, masterfully insightful and always seeking an explanation. He made indelible marks of value during his life both personally and professionally, and he will most certainly be missed."

Among the most influential of his papers (some of which were coauthored with collaborators) are as follows: his 1960 paper, which provided the first solution to a dynamical problem in finite elasticity; the 1966 paper concerning Saint-Venant's principle in linear elasticity theory; his 1972 paper on conservation laws in finite elasticity, path-independent integrals, and basic invariance principles; the series of papers during the period of 1973–1978 in which he showed how nonlinearities can lead to both quantitative and qualitative effects at various singularities; his papers in 1975–1978 on the loss of ellipticity of the equilibrium equations of finite



elasticity; the 1978 and 1979 papers concerning the dissipation of mechanical energy during quasi-static motions of elastic bodies; his 1990 paper on the driving force on a nonmaterial interface (in a not-necessarily elastic material); and the 1991 paper concerning the role of kinetic relations in the propagation of phase boundaries. These and other important papers written by Jim have advanced our knowledge in fundamental ways and will have a lasting influence on the field of solid mechanics.

As James R. Rice (Harvard) has said, "In his science the characteristic marks were precision and depth in showing the remarkable implications of the nonlinear elastic formulation in a wide range of settings, many untouched before. Among the gems along the way best known to me (and I understand that's just a fraction of his work) are his studies on nonlinear crack tip fields, …discontinuous deformation states, and …the dynamics of phase interfaces."

In 2006, Jim wove together all of his work on phase transformations into a monograph entitled *Evolution of Phase Transitions: A Continuum Theory* (Cambridge University Press) that he coauthored.

Jim was engaged in two sustained collaborations over his career. The first was with his Caltech colleague Eli Sternberg over the period of 1966–1983. They worked in finite elasticity, primarily on singular problems and the loss of ellipticity, though their work also included their landmark 1972 paper on conservation laws. The second, during the period of 1986–2009, was with his former doctoral student Rohan Abeyaratne. Their work was focused mostly on driving forces, kinetic relations, and the evolution of phase transitions in thermoelastic solids.

Jim served the academic community in a number of roles. He was a member of the editorial boards of several journals. He served as President of the American Academy of Mechanics in 1985–1986. His scholarly contributions have been recognized by numerous honors. He was a Fellow of the American Association for the Advancement of Science (AAAS), a Fellow of the American Academy of Mechanics, and a Fellow of the American Society of Mechanical Engineers (ASME). In 1985, he was awarded the Degree of Doctor of Science (*honoris causa*) by the National University of Ireland. The Society of Engineering Science awarded him with the Eringen Medal in 1991. ASME awarded him the Koiter Medal in 2002. The Journal of Elasticity dedicated an issue to Jim on the occasion of his 60th birthday for "seminal contributions made to the field of elasticity."

The clarity and precision of Jim's thoughts were visible in his classroom teaching and technical presentations. As Morton E. Gurtin (CMU) has said, "I first met Jim Knowles sometime in the period 1965–1970 at one of the early meetings of the Society for Natural Philosophy. He gave a talk on Saint-Venant's principle in two-dimensional linear elasticity theory. I have an incredibly vivid picture of him in the front of the room wearing a jacket and tie and writing on a standard issue portable blackboard. I remember thinking to myself what a beautiful talk, so clear and so interesting, possibly the best I had ever heard. And in thinking back I believe I can say the same thing today."

[1]This is an abbreviated version of an appreciation that appeared in Issue 1, Volume 98 of the Journal of Elasticity. It is printed here with permission of that journal and Springer.

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Jim inspired and influenced generations of students through his classes in applied mathematics and mechanics. He has been awarded numerous teaching prizes both at MIT and at Caltech. His treatment of linear algebra, in particular, was so beautiful and so well geared to those preparing to study continuum mechanics that when he stopped teaching Engineering Mathematics at Caltech, he was inundated with requests to write a monograph on the subject. And so, in 1998, he authored a textbook for graduate students entitled *Linear Vector Spaces and Cartesian Tensors* (Oxford).

Jim had a number of unusual mannerisms when he taught. For example when he lectured, he would often walk to the back of the class and study his blackboards from the rear of the room. A number of students who took his classes and are now professors emulate this practice, even in large lecture halls. In addition to giving lectures that were captivating and extraordinarily clear, Jim would frequently use unusual attention grabbing phrases at various moments. For example, once when referring to a long and tedious calculation that he was not going to work out on the blackboard, he said, "When you do the inversion, you get a little piece of junk sitting on a branch cut, so you walk away from the wreckage."

Jim has been greatly admired for the way in which he respected and mentored many younger researchers, including graduate students not being supervised by him. For example, Richard D. James (Minnesota) says that "Kaushik Dayal wrote to me recently saying how much he appreciated Jim's support while he was a graduate student working on the controversial area of peridynamics. This reminded me of Jim's similar attitude toward my early work in solid mechanics on phase transformations, including the mathematical work. He was very quick to encourage young people in areas that are controversial, not well settled, and perhaps even partly wrong." Ares Rosakis, Chair of Caltech's Division of Engineering and Applied Science says that "Jim was the greatest mentor I ever had. He would look for the spark in people's eyes and help them make their dreams a reality."

No description of Jim is complete without at least a brief mention of some of his personal attributes. His charm, humor, and warmth made him a much-loved colleague. He was exceptionally kind and truly a gentleman. Jim delighted in helping his grandsons with their mathematics and spent many hours figuring out how to motivate and excite 10-year olds. Long before diversity became a focus in faculty hiring at U.S. universities, Jim was a strong advocate for the women at Caltech. In fact, he was on the Board of Organization for Women at Caltech in the mid-1990s.

He delighted in coming up with clever quips. For instance, there was the time when Jim and Eli Sternberg were in the coffee room with a few students. One of the students leaves the room. After some time, Eli looks up and says, "Where is so-and-so?" Then, Jim gets this surprised look on his face, raises his eyebrows, and says, "He has vanished identically!" And then there is the classic Jim Knowles opening line in his monograph on linear algebra: "When we are young, we learn that vectors are arrows."

Although Jim was uncompromisingly serious in maintaining high scientific standards, he never took himself too seriously. In one of his last conversations, he said to a collaborator, "We sure had fun as we worked on our research, didn't we? Even when it wasn't going well, we still had fun."

Jim leaves behind a legacy of enduring scientific contributions, and the memory of a warm and caring teacher, mentor, colleague, and friend. He will be greatly missed.

James K. Knowles: May the (Driving) Force be with you.

Rohan Abeyaratne
Massachusetts Institute of Technology