CHANCHAL KUMAR MAJUMDAR

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C. K. Majumdar

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(1938-2000)

Elected Fellow 1982

CHANCHAL KUMAR MAJUMDAR, a physicist of exceptional calibre and an outstanding scholar passed away on June 20, 2000. He was internationally renowned for his pioneering contributions in condensed matter theory, statistical mechanics and quantum many body problems. He was a perfectionist and this was evident in his research, teaching and writing. He was a person of rare honesty and never compromised on his principles. He was moreover an idealist and a dreamer and was indefatigable in promoting the cause of science.

FAMILY BACKGROUND AND EDUCATION

Majumdar was born on August 11, 1938 in Calcutta to Sita and Nirmal Kanti Majumdar. His father was a renowned professor of political science respected for his vast erudition. Majumdar and his two brothers, Ujjal and Mukul, in their turn, were remarkably brilliant students during their school, college and university years. Majumdar studied in St. John's CMS School, Krishnanagar, West Bengal, Presidency College, Calcutta and University College of Science, Calcutta. He stood first in all the examinations obtaining record marks. His capacity for acquiring knowledge appeared to be limitless, he read extensively and on a wide range of subjects. Added to this were his prodigious memory and sharp intellect. Majumdar spent one year (1960-61) in the Saha Institute of Nuclear Physics as a Post-M.Sc. student and then left for the University of California (La Jolla), USA for doctoral studies. He obtained his Ph. D. degree in Physics in 1965. In 1968 he married Utpala Ghosh who was highly accomplished and proved to be his ideal partner.

Professor Majumdar's advisor was the Nobel Laureate Maria G Mayer and his thesis supervisor, Walter Kohn, who later became a Nobel Laureate. Majumdar kept in touch with Kohn throughout his life. Kohn came all the way from America to Calcutta in January, 2002 to deliver the first Chanchal Kumar Majumdar Memorial Lecture held at the Indian Association for the Cultivation of Science. At the beginning of his lecture, Kohn expressed his profound admiration for Majumdar and his deep sense of loss at the passing away of his beloved student.

PROFESSIONAL AND RESEARCH CAREER

Majumdar came back to India in 1966 and joined the Tata Institute of Fundamental Research (TIFR), Mumbai as a Fellow. During his tenure at TIFR, Majumdar with a few colleagues and students and the foundations of research in condensed matter physics in India. Majumdar was well-known for his outstanding mathematical abilities. At the same time he pioneered large-scale numerical computations in the country. His eminence as a teacher began to be established during this time. He taught several courses at TIFR. Graduate School (1966-1974) and at the Summer Schools on Advanced Quantum Mechanics. He left TIFR in 1975 to join the Physics Department of Calcutta University as Palit Professor. Majumdar came to Calcutta with the aim of rejuvenating physics education and research in the University. He firmly believed that, where higher education and research were concerned, development of universities should get the topmost priority. Universities, he felt, should attract the best scientific talent in the country so that excellence in both teaching and research is achieved. In one of his writings on the subject, he mentions " the strategy of having a few world class research establishments in India to maintain visibility in world science." He further adds, " One has to admit that the strategy has good points too. But research and teaching in general in Indian universities has suffered in the process."

In his teaching at the Calcutta University, Majumdar set the highest standards of rigour and perfection. He was an inspired teacher and forgot about time while immersed in lengthy mathematical calculations on the blackboard. His students loved and revered him. There are several amusing anecdotes regarding his interaction with them. In class, he would often call a student to the blackboard to work out a problem. Fear of being called to the blackboard prompted some of them to disappear before the beginning of class. Majumdar, with twinkling eyes and a mischievous smile, was sure to ferret them out of their hiding places in the canteen or some remote corner of the Physics Department.

He modernized the Departmental Library and experimental laboratories and would spend long hours in the laboratories setting up new experiments. Over a period of several years, he gave weekly lectures on a variety of topics to the research community in Calcutta. Attending his lectures was an unforgettable experience, specially, witnessing his feat of deriving lengthy and difficult mathematical calculations on the board without the aid of notes. He provided active help to many research groups in Calcutta and motivated some of them to take up challenging problems. In fact, his doors were always open to students as well as others in need of his help and he rarely said 'no' to a request. He would, on request, translate a scientific paper written in French, provide solution for a particularly difficult mathematical problem, give a set of lectures on astrophysics to school students in a remote village, speak on modernization of libraries at a book fair – the list was multifarious and endless. During his later years in Calcutta, he took up experimental research programmes. A well-known theoretical physicist, who was also a close friend of Majumdar, once remarked, " Some of us have Chanchal's ability for doing difficult theoretical calculations. We cannot, however, construct a complicated electronic circuit which he can !"

Majumdar joined the Indian Association for the Cultivation of Science, Calcutta in 1982 and was there till 1987. Subsequently he became the Founder Director of the S. N. Bose National Centre for the Basic Sciences in Calcutta. The fledgeling Centre was almost like his child and he took great care in nurturing it and promoting quality research activity there. He retired from the Centre in February, 1999. He joined the Indian Statistical Institute, Calcutta as Emeritus Senior Scientist of the Indian National Science Academy. He started working on a project concerning research in magnetism in India. His untimely death left his students, colleagues and admirers in profound shock. Majumdar made significant contributions in several areas of condensed matter theory, quantum many body problem and statistical mechanics which brought him considerable international acclaim and recognition. A summary of some of his important contributions is given below.

SCIENTIFIC CONTRIBUTIONS

Positron Annihilation in Metals (PAM)

PAM is an useful technique for the analysis of various electronic properties of metals. A positron, on introduction into a metal, encounters an electron and the electron-positron pair annihilates giving rise to two gamma rays. One of the important experimentally measured quantities is the angular correlation of the gamma rays emanating from an annihilating event. Majumdar studied the effect of interactions, both electron-electron and electron-positron on PAM. In contrast to positron lifetimes, the angular correlation curve was found to be consistent with the predictions of free electron theory. The characteristic feature of normal metals is a sharp Fermi surface. This is the surface in momentum space at which a sharp discontinuity in the electron momentum distribution occurs at absolute zero temperature (T =0). The Fermi surface, Majumdar showed, causes a sharp break in the angular correlation curve even if interactions are considered so that experimental investigation of the true Fermi surface of the interacting system of electrons is possible.

Majumdar further proposed an experiment to measure the effective mass of positrons in metals. On raising the temperature of a metal, the positron picks up thermal motion more quickly than the electrons as the latter are constrained by the Pauli exclusion princple. Since electrons move in response to the motion of positrons, the effective mass of the latter differs from the free mass. Majumdar's proposal was that the effective mass can be determined from the temperature dependence of the angular correlation curve. Such experiments have been routinely performed to determine the effective mass of the positron in metals.

The two-dimensional angular correlation of annihilation radiation (2D ACAR) experiments measure the distribution of one or two components of the total momentum of the annihilating pair. Majumdar showed that information about the distribution of the total momentum can be obtained by appropriate analysis of the 2D ACAR data. The 2D ACAR experiments have been performed extensively in recent times in studies of metals, alloys and high temperature superconductors.

Many Body Problems and Magnetism

Kohn and Majumdar proved a theorem (later known as the 'Kohn-Majumdar theorem') on the continuity between the bound and unbound states in a noninteracting Fermi gas enclosed in a spherical box containing a spherically symmetric potential at the centre. In contrast to the single atom problem, the transition between bound and unbound states is smooth so that the properties of the entire system do not exhibit any nonanalyticity at the transition points. Similar conclusions are expected to be true under more general conditions, e.g., finite temperature, a periodic array of potentials and inclusion of sufficiently weak interactions. Experimental observations on dilute, nonmagnetic alloys and metallic Ce are in conformity with the predictions of the theorem.

The magnetic properties of insulating solids are well described by the Heisenberg exchange interaction Hamiltonian

$$H = -J\sum_{<ij>} S_i . S_j$$

$\mathbf{S}_i$ and $\mathbf{S}_j$ denote spins sitting at the lattice sites i and j and J is the strength of the exchange interaction. The sign of J determines whether the interaction is ferromagnetic (FM, $J > 0$) or antiferromagnetic (AFM, $J < 0$). In the first (second) case, the interacting spin pair tends to be parallel (antiparallel). Consider the spin-1/2 FM Heisenberg Hamiltonian with interaction only between nearest-neighbour (NN) spins. The lowest energy state, i.e., the ground state of the Hamiltonian is simple and has all the spins parallel, say, pointing upwards. The magnetic moments associated with the spins add up giving rise to the large moment of a ferromagnet. If one spin is turned over, it moves in the spin chain giving rise to an excitation known as a spin wave or a magnon. If two spins are flipped, they can move independently or together occupying NN lattice positions. The latter case describes a magnon bound state. In the general case of r magnons, Bethe, using the well-known Bethe Anstz (BA), derived the eigenvalue of the r-magnon bound state. The BA suggests a form for the eigenfunction but the structure is not sufficiently explicit. The two-magnon problem has been completely solved in the work of Dyson, Hanus, Wortis, Fukuda and others.

Majumdar first formulated the three-magnon bound state problem using Faddeev's three body equations. The integral equation was originally solved numerically for both the isotropic and longitudinally anisotropic Heisenberg Hamiltonians. Later, for the isotropic case, the integral equation was solved in an exact, analytic manner and the physical eigenfunction as well as the eigenvalue of the three magnon bound state problem were completely determined. This is one of the few examples of an exact, analytic solution of a non-trivial three body problem. Magnon bound states in linear chain compounds have been detected experimentally. The Hamiltonian displayed earlier describes an antiferromagnet if J is < 0. For the spin-1/2 linear chain in which only the NN spins interact, the ground state energy and the low-lying excitation spectrum can be determined exactly using the BA. The ground state wave function has a complicated structure as described by the BA. Majumdar and his student. Dipan K Ghosh proposed an AFM model Hamiltonian for which the exact ground state can be explicitly written down. The ground state is doubly degenerate and has a simple structure: alternate spin pairs are in singlet spin configurations in the ground state. Determination of the exact ground state of a many body Hamiltonian is in general a formidable task and the Majumdar-Ghosh chain provides an example of a many body system with a simple ground state. The MG model is now considered to be a landmark achievement in the area of exactly-solvable many body systems and has given rise to a large body of work on interacting spin systems, both in India and abroad. The model has a spin disordered ground state and has acquired special significance after the discovery of high temperature superconductors in which spin-disordered states play a prominent role. Some AFM compounds have been discovered recently which share similar physical features with the MG model.

Statistical Model and Computational Studies

Phase transitions and critical phenomena constitute an important area of study in statistical mechanics. In the vicinity of the critical point, the characteristic quantities of a system (e.g. the thermodynamic functions) become singular in a power-law fashion and the exponents in the power are known as the critical exponents. The magnitude of the exponents depends on the dimensionality of the system and the number of components of the order parameter and not on the specific system. Critical phenomena have universal features and widely different systems belong to the same universality class if the corresponding critical exponents have the same values. Powerful numerical and analytical techniques like series expansions, Padé approximants and the renormalization group are available for calculating the critical parameters and exponents. Majumdar formulated a variant of the series expansion method in which the critical parameters and exponents are determined from the distribution of the zeros of the so-called cluster polynomials in the complex plane of some appropriate variable. The cluster polynomials appear in the low-density linked-cluster expansion of the free energy. The method is partly analytical and partly numerical and has been applied to both discrete models like the FM and AFM Ising models as well as to continuum models like the gas-liquid transition. For the latter case and with the pair potential having the Lennard-Jones form, the calculated critical parameters and exponents are in good agreement with the empirical data for inert gases. Some of the numerical results led to conjectures which were proved later.

Majumdar made an important contribution in the area of disordered solids. The time dependence of the stress relaxation in stabilized soda-lime glass was earlier studied by R Douglas, S F Edwards and others. Majumdar provided a simple explanation for the form of the non-exponential decay and a formula which gives the right order of magnitude of the long time scales involved. Majumdar pioneered computational studies in condensed matter physics in India. He and his co-workers applied state-of-the-art computational techniques to a variety of important problems like electronic band structure calculations of alpha and gamma-cerium, lower bound to the ground state energy of the Heisenberg Hamiltonian on a triangular lattice and the thermodynamic and dynamic properties of finite-sized spin chains and clusters.

Experimental and Applied Research

When Majumdar joined the Physics Department of Calcutta University as Palit Professor, he looked up the Trust Deed of Taraknath Palit and found that the Palit Professor was expected to run a laboratory. This motivated him to start planning experiments. The choice of experiments was dictated by both practical considerations (lack of financial resources in the University and shortage of trained manpower) as well as a desire to make use of the expertise available in the other Departments of the university and neighbouring Institutes. In the succeeding years, he initiated some interesting experimental research programmes in collaboration with students and other scientists.

One of these programmes was the Mössbauer study of the phenomenon of corrosion and its inhibitors. The rate of corrosion was determined through a measurement of the diffusion constant. A systematic investigation of some inhibitors of corrosion was also made. The relevance of the study comes from the fact that iron is the most widely used mineral in industry and corrodes easily due to atmospheric humidity. An interdisciplinary collaborative programme on rock magnetism involving physicists, chemists and geologists was further undertaken. Iron ore samples from different regions of eastern India were collected and the ferrous-ferric ratio in the samples was determined. Such measurements provide useful knowledge on the geochemical history of the ore. Majumdar was also associated with the radiation damage work carried out with the alpha-beam of the Variable Energy Cyclotron Centre, Calcutta on high-temperature superconducting cuprate samples. The critical temperature of the Bi-Sr-Ca-Cu-O sample was found to increase considerably on alpha-irradiation. He collaborated on various other experiments involving cuprate systems. Majumdar further undertook an important fluid dynamical study of the Hoogly estuary. The river is prone to formation of shoals, sandbanks and islands in its lower reaches. This has given rise to operational problems in the vicinity of the Haldia port. Majumdar and co-workers, in active collaboration with the Calcutta Port trust, developed a hydrodynamical numerical model of the Estuary Problem. Extensive computer simulation of the model provided significant insights on the remedial measures necessary to control the appearance of unwanted formations in the river. In an article titled Roots of Physics Research, Majumdar mentioned monsoon dynamics as another problem of great practical interest.

He felt that scientists need to be involved in greater numbers to work on similar problems in active collaboration with relevant government agencies like the Port Trust and Meterological Office. To quote him, "I do not belittle the difficulties of such collaborations; they may be more than those of the scientific problem. But somewhere sometime a beginning has to be made." In the same article, he raised the question "What is the aim of scientific research?" His answer was "It is the journey along the road to infinity that matters. And that journey has to be performed with dedication and scrupulous honesty." At the end of the article, he quoted from Robert Browning,with apologies for changing the context of the poem,

> "Look at the end of work, contrast
> The petty Done, the Undone vast,
> This Present of theirs with the hopeful Past!"

It was this feeling of 'Undone Vast' which drove Majumdar to take up endless tasks to the detriment of his health.

AWARDS AND HONOURS

Majumdar won several awards and prizes including the S. S. Bhatnagar Prize in the Physical Sciences (1976), Meghnad Saha Memorial Medal of the Asiatic Society (1978), UGC National Lecture in Physics (1978-79), P. A. Pandya Award of the Indian Physics Association (1979), Meghnad Saha Award for Theoretical Studies (UGC) (1983), Satyendranath Bose Medal of the Indian National Science Academy (1989), Santanu Ghosh Medal (Indian Science News Association, Calcutta 1991), Satyendranath Bose Birth Centenary Award of the Indian Science Congress Association (1997) etc. He was a Fellow of the Indian Academy of Sciences (Bangalore), the Indian National Science Academy (New Delhi), the National Academy of Sciences (Allahabad) and the American Physical Society. Twelve students obtained their Ph. D. degrees under his supervision. He published several research papers as well as miscellaneous writings in both Bengali and English. Precision and lucidity were the hallmarks of his writings. He had vast knowledge in subjects as diverse as history and philosophy.

Professor Majumdar was very close to his family. His daughter Ruchira and son Rupak are now in the U. S. A. Ruchira has a Ph. D. degree in Applied Mathematics and is at present teaching. Rupak has completed doctoral studies in theoretical computer science from the University of California, Berkeley. He currently holds a faculty position in Computer Science at the University of

California, Los Angeles. Majumdar was very fond of his students. He continued to teach in Calcutta University even after he left it. He would undertake long and exhausting bus journeys from his home to take classes. He left a message at the corner of the blackboard for the students to contact him at home if they faced any difficulty in their studies. A few days later, he passed away but the message was kept on the blackboard for several more months. When Majumdar was the Director of the S.N. Bose Centre, he went personally to the students of the Centre to convey messages to them. There are several anecdotes regarding his interaction with students during both his T. I. F. R. and Calcutta years and his old students were never tired of repeating some of these when chance brought them together.

Majumdar led a very simple life, he preferred the world of books to the one of material possessions. His character and qualities are reminiscent of those of the great son of Renaissance Bengal, Pandit Iswar Chandra Vidyasagar. Like him, Majumdar was deeply devoted to his mother, his scholarship was vast, he was a rare example of honesty and forthrightness, never sacrificing his integrity for personal convenience, he was tireless in the cause of education and lastly, he was extremely kind hearted and extended help to anyone who needed it. One can add to this Majumdar's outstanding contributions in condensed matter physics. Posterity will remember him as a great physicist, a great scholar, a great teacher and above all as someone who dared to dream and forsook the easy path in pursuit of an ideal.

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