

Experimenting with the Quantum World. S. T. Lakshmikumar. Vigyan Prasar, A-50, Institutional Area, Sector 62, Noida 201 307. 2007. 177 pp. Price: Rs 95.

The science that describes the behaviour of matter and energy on the scale of atoms and subatomic particles/waves accurately is called quantum mechanics. Since its christening by Max Born in 1924, it has turned out to be the foundation of several disciplines, like condensed matter physics, particle physics and quantum chemistry. Of late, quantum mechanics has been playing an important part in the development of nanotechnology and electronics.

With more than a century of experimental and applied scientific work, quantum theory has proven itself to be highly successful and practical. It all started in the 1900s with work of Max Planck, Albert Einstein and Niels Bohr, but gained prominence only in 1924 with the work of Louis de Broglie on matter waves. Other prominent contributors during that era that built a strong theoretical foundation of this subject were Werner Heisenberg, Erwin Schrodinger, Wolfgang Pauli, Max Born and Paul Dirac. Later, in 1947, the field was further expanded with the development of quantum electrodynamics by Schwinger, Tomonaga and Feynmann, and quantum chromodynamics by Gell-Mann.

This book is an attempt to describe the fascinations and 'uncertainties' of the quantum world. With advances in experimental techniques, it is possible today to visualize a photon as a particle and an electron as a wave. The book begins by introducing the dual nature of quantum

objects and their properties like uncertainty, entanglement and decoherence.

The second chapter dwells with the birth of quantum mechanics by describing many path-breaking experiments that led to the establishment of the dual nature (particle and wave) of quantum objects. Although the Huygens and Young's experiments in the 18th and 19th century, demonstrating the wave nature of light which seriously challenged Newton's corpuscular theory, could be considered as first evidences to the dual nature, it was not until 1900 with the advent of Planck's hypothesis, that we got clues to the quantum nature of particles. In this chapter, the author describes the clues to the existence and actual discovery of the smallest particle with mass – the electron. The quantum nature of the electron is described through a series of experiments like the Davisson-Germer experiment, which describes the wave nature of the electron and the recent experiment by Tonamura *et al.* using a special electron microscope, demonstrating single electron interference. To use the authors' own words 'this experiment is one of the most beautiful of all quantum experiments and demonstrates the strange nature of the particles'.

Quantum mechanics developed from the study of electromagnetic waves through spectroscopy. The blackbody spectrum was correctly predicted using Planck's hypothesis, which meant that the radiating body consisted of a large number of oscillators vibrating with a certain frequency, from zero to infinity, and the energy of such an oscillator could only take values that were proportional to integral multiples of frequency. It meant that energy was carried in small packets (quanta), called photons. This discovery seemed to convert waves into particles. Experiments demonstrating photons as particles (Compton effect, photoelectric effect) and their dual nature (single photon interference) are well described in chapter 2.

Another important concept which provides clues to the quantum nature of the particles is the absence of superluminal signals. This is also described in the second chapter through the Michelson-Morley experiment and Einstein's special theory of relativity. Polarization of light and spin of an electron are other concepts which also underline photons and electrons as quantum entities.

It is normally assumed that quantum mechanics belongs to the realm of very small. But the collective behaviour of these small quantum particles forms the basis of all macroscopic (classical) phenomena. The number of phenomena that can be explained by quantum mechanics is enormous. A qualitative description of collective behaviour of quantum particles has been made in chapter 3 by considering two types of quantum particles – bosons and fermions.

Bosons are particles with integral spin which include 'particles' like photons, phonons (quanta of lattice vibration), etc. Collective behaviour of photons has led to an important discovery of laser (light amplification by stimulated emission of radiation). The concept of laser is based on population inversion, wherein the probability of occupation of higher energy level becomes more favourable than the lower level. Therefore, when all these particles make a transition from higher to lower level, they emit photons of only a particular frequency and which are in phase (coherent) with each other. Formation of a condensed state is another property associated with bosons and has been nicely described in the third chapter. A condensed state or coherent state, wherein all the bosons occupy the same energy level can be made possible in atoms with even number of protons, neutrons and electrons, for example, helium. A consequence of this condensed state is superfluidity which helium exhibits below 2.17 K. The book also lucidly describes the recent experiments demonstrating the bosonic character of atoms. Here, a small number of rubidium atoms is confined to a small region inside an ultrahigh vacuum chamber at very low (10^{-7} K) temperatures. In this case, the rubidium atoms behave exactly like the helium atoms. In addition to condensation, these experiments allow confirmation of other quantum properties like interference, entanglement and tunnelling.

The latter half of chapter 3 describes the collective behaviour of fermions. Beginning with the building of atoms, their pairing to form molecules and solids, this part describes the properties which atomic electrons exhibit as free electrons when atoms come together to build a solid. Collection of a large number of atomic energy levels leads to the formation of energy bands. Different energy bands are separated from one

another by a forbidden gap that results due to the underlying periodic atomic/ionic potential. The degree of filling up of the topmost energy band (valence band) gives rise to a classification of solids as metals, insulators and semiconductors. The properties of semiconductors can be tuned by impurity concentration. This leads to the formation of *n*-type (electron rich) and *p*-type (electron deficient or hole-rich) semiconductors. A junction of *p*-type and *n*-type semiconductor has a rectifying nature and forms the basis of another revolution called electronics.

The transition of atoms to solids has also been described using the Landau approach of broken symmetry. This approach is powerful. In a system obtained by broken symmetry, the distribution of energy among the entire set of particles can be approximately described as 'quasiparticles'. These new quantum entities can be either fermionic or bosonic in character and can be experimentally investigated. Different quantum objects such as phonons, magnons, plasmons, excitons, polarons and Cooper pairs that lead to superconducting state in solids have been described briefly in the third chapter. The effect of dimensionality that leads to observation of fractional quantum Hall effect has also been discussed here.

The development of quantum theory not only enriched our understanding of nature, but also led to many technological revolutions. The two such technologies that have revolutionized human life are electronics and lasers. Discovery of the transistor about 60 years ago, signifies the birth of a modern age. We have moved from bulky and cumbersome, valve-based devices to small and easy-to-use 'systems on chips'. The development of other semiconducting devices purely based on quantum fundamentals like tunnel diode, field effect transistor (FET), metal-oxide semiconductor FET (MOSFET), etc. have enabled us to reap benefits in terms of computers, communication and dissemination of information through the internet. Discovery and development of lasers is another area that has touched every sphere of our lives. Its important property of directionality immediately finds use in diverse fields like medicine, machine and tools, defence, nuclear and even entertainment industry. Another quantum phenomenon that has and will continue to revolutionize

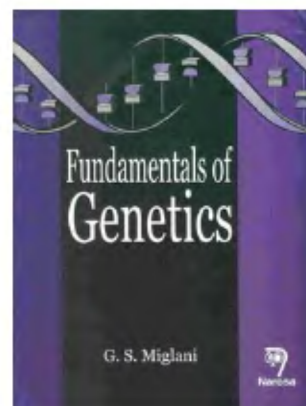
human life in general is superconductivity. The superconducting quantum interference device, which is based on Josephson tunnelling effect, is the most sensitive detector of magnetic flux and has been a boon to the field of neuroscience. The giant magneto resistance-based read-write heads useful in high-density data storage and transfer, carbon nanotube electronics, microelectromechanical systems which could also be called atomic machines are, to name a few, the other quantum technologies knocking at our doorstep.

Finally, the author describes some thought experiments that were designed to test the limits of quantum physics and have now been actually performed. One of the most famous examples is the Einstein, Podolsky and Rosen paradox, which has now been explained using arguments based on entangled spins. The other experiments described are those testing the wave particle duality of quantum objects, quantum decoherence, measurement without interaction, quantum zeno, etc. The recent discovery of cold atoms has made it possible to verify the findings of the Heisenberg microscope thought experiment, that uncertainty is not caused by transfer of momentum from photon to particle. These experiments are essentially performed, as the author himself has put it, with the spirit of a mountaineer. The experiments described in this chapter are quite recent and are expected to improve the precision of measurement techniques, but some of them also have technological possibilities like quantum cryptography, quantum computing, etc.

The final chapter conveys the overall message of this book. The book is well written and emphasizes the breadth, depth and utility of quantum approach as well as points out the futility of counter-intuitive ideas. Although the book is silent on discoveries and predictions of particle physics, it is a must read for all students of physics, as it will not only make them abreast with the recent developments in the field, but also help them understand the quantum phenomena in a better way.

KAUSTUBH R. S. PRIOLKAR

*Department of Physics,
Goa University,
Goa 403 206, India
e-mail: krp@unigoa.ac.in*



Fundamentals of Genetics. G. S. Miglani. Narosa Publishing House, 22 Delhi Medical Association Road, Daryaganj, New Delhi 110 002. 2008. 660 pp. Price not mentioned.

As mentioned in the Preface, this textbook aims 'to make concepts and principles of genetics clear to the undergraduate students, using a simple language'. Although students are introduced to the area of genetics right from their school days, a large percentage of the undergraduate as well as postgraduate students only knows facts (like ratios obtained from different crosses), without really understanding the reasons or concepts behind these observations. Thus, a book explaining the fundamentals of genetics is of prime importance to students. Keeping in line with the recent trends, the book also envisages to explain various phenomena of genetics at the molecular level, wherever possible. The book is organized in 28 chapters ranging from principles of inheritance, chromosomal theory of inheritance, gene-gene interactions, genetic analysis of haploid and diploid organisms, gene function and regulation, population genetics, developmental genetics, etc. The book ends with a chapter on probability and chi-square. Each chapter apart from stating the concerned phenomenon cites examples, some of which are interesting, and ends with a section on 'Some useful reading hints', which is followed by questions.

However, after going through the book I felt that it does not meet the goal which the author has projected in the Preface. A book on the fundamentals of genetics, which introduces probability as the last chapter is not expected to help students understand the concepts of genetics. At best the book is a bag of facts, some in-