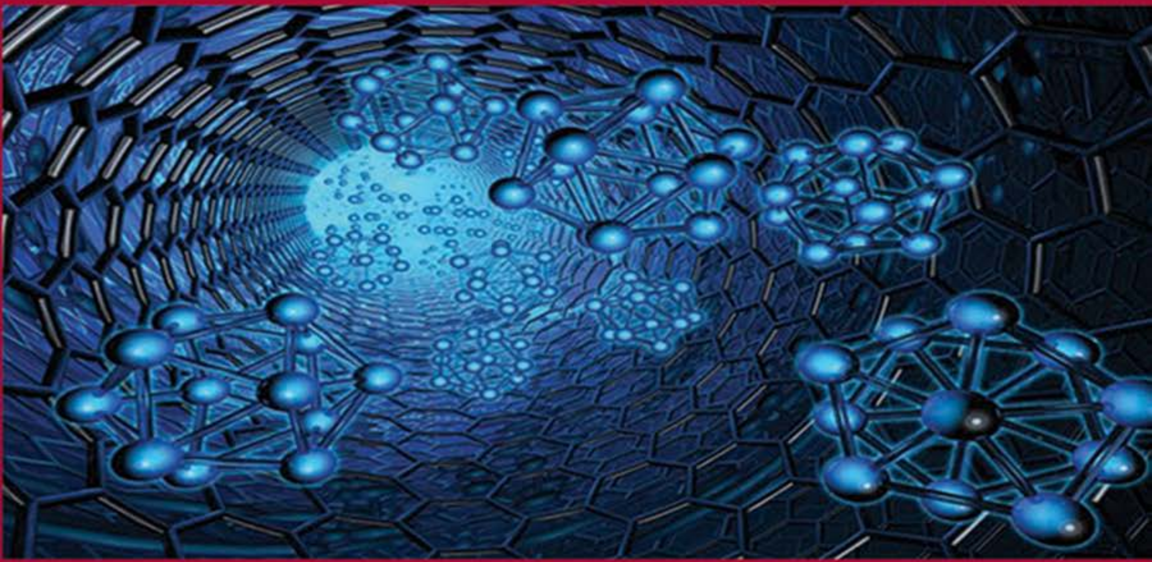

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Vibrations, Buckling, and Ballistic Impact

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Preface

I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle. This field is not quite the same as the others ... Furthermore, a point that is most important is that it would have an enormous number of technical applications. What I want to talk about is the problem of manipulating and controlling things on a small scale.

Richard Feynman

Carbon nanotubes (CNTs) were discovered by Sumio Iijima of the NEC Corporation in the early 1990s. Since then, extensive research activities on CNTs have been initiated around the world. This interest is attributed to the extraordinary mechanical properties and unique electrical properties of CNTs and their potential applications. Meyyappan [MEY 05] remarked that "the breadth of applications for carbon nanotubes is indeed wide ranging: nanoelectronics, quantum wire interconnects, field emission devices, composites, chemical sensors, biosensors, detectors, etc … The community is beginning to move beyond the wonderful properties that interested them in CNTs and are beginning to tackle real issues associated with converting a material into a device, a device into a system, and so on". In a broader sense, Liu *et al.* [LIU 06] stressed that "nanotechnology is making, and will continue to make, an impact in key areas for societal improvement".

For the reader who is new to the world of nanotechnology, we quote from the book by Rogers *et al.* [ROG 08]: "The 'nano', from which this relatively new field derives its name, is a prefix denoting 10^{-9}. 'Nano' comes from *nanos*, a Greek word meaning dwarf. In the case of nanotechnology, it refers to things in the ballpark that are one-billionth of meter in size. While in graduate school in 1905, Albert Einstein took experimental data on the diffusion of sugar in water and showed that a single sugar molecule is about one nanometer in diameter … Nobel laureates, novelists, and news anchors alike tell us on a daily basis that nanotechnology will completely change the way we live. They have promised us microscopic, cancer-eating robots swimming through our veins! Self-cleaning glass! Digital threads! Electronic paper! Palm-sized satellites! The cure for deafness! Molecular electronics: Smart dust!".

This book deals with specific aspects of CNTs only, namely their vibrations, buckling, impact buckling, and nanosensors. For vibration and buckling analyses, we use the classical Bernoulli–Euler theory of beams. However, as it turned out recently, long CNTs may pose health risks that are similar to those found in asbestos, with possible diseases such as mesothelioma or cancer of the lining of the lungs as well as adverse effects on the male reproductive system. Since long CNTs are harmful whereas short CNTs are not, we must use the short CNTs along with the theory that is appropriate for the short CNTs. Specifically, we use Bresse–Timoshenko theory for short CNTs because when the length to diameter ratio is relatively small, transverse shear deformation and rotary inertia must be accounted for. We use a consistent and simple version of Bresse–Timoshenko theory that has been recently developed by the first author. This analysis leads to simple expressions for natural frequencies. A theory of nanosensors is presented to identify the possibility of attached virus or bacterium. Both long and short CNTs may be regarded as nanosensors.

This promise of "the next big idea of nanotechnology" virtually forces us to contribute, at least in some small manner, to the noble goals above. This book deals with CNTs. We owe our gratitude to many scientists around the world. It is our pleasure to record appreciation to several individuals with whom we discussed our findings (as listed in alphabetical order): Professor Sondipon Adhikari, University of Swansea, United Kingdom; Professor Romesh Batra and Dr. S.S. Gupta of the Virginia Polytechnic Institute and State University, USA; Professor Qing Chen of Peking University, People's Republic of China; Professor Jean-Michel Claverie of Institut de Microbiologie de la Méditerannée, France; Professor Moshe Eisenberger of the Technion-Israel Institute of Technology, Israel; Dr. Rivka Gilat, University of Ariel, Israel; Professor Lin Guo and Professor L.D. Li of the

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We will be most grateful to the readers if they will be so kind as to communicate to us their constructive comments on both the content of this multi-continental effort and on possible extensions and cooperations.

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