Preface

The creation of Nano Electronics, the subset of the generalized set Physics, is based on the following two important concepts:

- The symmetry of the wave vector space of charge carriers in electronic materials having various band structures is being reduced from a 3D closed surface to a quantized 2D closed surface, quantized non-parabolas and fully quantized wave vector space leading to the formation of 0D systems such as ultrathin films (UFs), doping superlattices, inversion and accumulation layers, quantum wells (QWs), quantum well superlattices, carbon nanotubes, nanowires (NWs), quantum wire superlattices, magnetic quantization, magneto size quantization, quantum dots (QDs), magneto inversion and accumulation layers, magneto quantum well superlattices, magneto NIPIs, quantum dot superlattices and other field aided nanostructures.

- The advent of modern experimental methods, namely Fine Line Lithography (FLL), Metallo-Organic Chemical Vapor Deposition (MOCVD), Molecular Beam Epitaxy (MBE), etc., for fabricating low-dimensional nanostructured systems.

Quantum confined materials have gained much interest in modern physics because of their importance to unlock both new scientific revelations and multi-dimensional altogether unheard of technological applications. In UFs, quantization of the motion of carriers in the direction perpendicular to the surface exhibits the two-dimensional carrier motion of charge carriers, and the third direction is being quantized. Another one-dimensional structure known as NWs has been proposed to investigate the physical properties in these materials, where the carrier gas is quantized in two transverse directions and they can move only in the longitudinal direction. As the concept of quantization increases from 1D to 3D, the degree of freedom of the free carriers decreases drastically and the total density-of-states (DOS) function changes from Heaviside step function to the Dirac’s delta function forming QDs which, in turn, depend on the carrier energy spectra in different materials. An enormous range of important applications of such low-dimensional
structures for modern physics in the quantum regime, together with a rapid increase in computing power, have generated considerable interest in the study of the optical properties of quantum effect devices based on various new materials of reduced dimensionality. Examples of such new applications include quantum switches, quantum registers, quantum sensors, heterojunction field-effect, quantum logic gates, quantum well and quantum wire transistors, quantum cascade lasers, high-frequency microwave circuits, high-speed digital networks, high-resolution terahertz spectroscopy, advanced integrated circuits, superlattice photo-oscillator, superlattice photo-cathodes, resonant tunneling diodes and transistors, superlattice coolers, thermoelectric devices, thin film transistors, micro-optical systems, intermediate-band solar cells, high performance infrared imaging systems, optical modulators, optical switching systems, single electron/molecule electronics, nanotube-based diodes, and other nanoelectronic devices [1–14].

Although many new effects in quantized structures have already been reported, the interest in further research of different other aspects of such quantum-confined materials is becoming increasingly important. One such significant concept is the Dispersion Relations (DRs) of carriers in semiconductors and their nanostructures, which occupies a singular position in the arena of Modern Physics and related disciplines in general and whose importance [15–36] has already been established since the inception of the theory of band structure of Solid State Physics. The concept of DRs is of fundamental importance for not only the characterization of semiconductor nanostructures, but also for the study of carrier transport in semiconductors and their quantized counterparts through proper formulation of the Boltzmann Transport equation which, in turn, needs the corresponding carrier energy spectra of the heavily doped materials and is still one of the open research problems. It is important to note that six important transport quantities, namely the effective carrier mass (ECM), density-of-states (DOS) function, the sub-band energy and the measurement of band gap in the presence of strong light waves, intense electric field and heavy doping are in disguise in the very important concept of DR. Besides, the acoustic mobility limited momentum relaxation time is inversely proportional to the respective DOS function of a particular semiconductor and integral over the DOS function leads to carrier statistics under the condition of extreme carrier degeneracy which, in turn, is connected to the 25 important transport topics of quantum effect devices, namely the Landau Dia and Pauli’s Para Magnetic Susceptibilities [37], the Einstein’s Photoemission [38], the Einstein Relation [39], the Debye Screening Length [40], the Generalized Raman gain [41], the Normalized Hall coefficient [42], the Fowler-Nordheim Field Emission [43], the Gate Capacitance [44], the Thermoelectric Power [45], the Plasma Frequency [46], the Magneto-Thermal effect in Quantized Structures [47], the Activity coefficient [48], the Reflection coefficient [49], the Heat Capacity [50], the Faraday rotation [51], the Optical Effective Mass [52], the Carrier contribution to the elastic constants [53], the Diffusion coefficient of the minority carriers [54], the Nonlinear optical response [55], the Third order nonlinear optical susceptibility [56], the Right-Leduc coefficient [57], the Electric Susceptibility [58], the Electric Susceptibility Mass [59], the
Electron Diffusion Thermo-power [60] and the Hydrostatic Piezo-resistance Coefficient [61] respectively.

The present monograph solely investigates DRs in heavily doped nanostructures of nonlinear optical, III–V, II–VI, gallium phosphide, germanium, platinum antimonide, stressed, IV–VI, lead germanium telluride, tellurium, II–V, zinc and cadmium diphosphides, bismuth telluride, III–V, II–VI, IV–VI and HgTe/CdTe quantum well HD superlattices with graded interfaces under magnetic quantization, III–V, II–VI, IV–VI and HgTe/CdTe HD effective mass superlattices under magnetic quantization, quantum confined effective mass superlattices and superlattices of HD optoelectronic materials with graded interfaces in addition to other quantized systems. Incidentally, even after 40 years of continuous effort, we see that complete investigation of the DR comprising the whole set of HD materials and allied sciences is really a sea and permanently enjoys the domain of impossibility theorems. DRs have different forms for different materials and change under one-, two- and three-dimensional quantum confinement of charge carriers. It is rather curious to note that for the 31 important concepts, only 6 monographs have been written [62–67] and the remaining 25 books will appear in the future, hopefully from the readers of this book. In this context, it may be mentioned that the available reports on the said areas cannot afford to cover even an entire chapter containing detailed investigations on DRs in semiconductors and their quantized structures.

It is worth remarking that the effects of crossed electric and quantizing magnetic fields on the transport properties of semiconductors having various band structures have been relatively less investigated compared to the corresponding magnetic quantization, although the study of cross-fields is of fundamental importance with respect to the addition of new physics and related experimental findings in modern quantum effect devices. It is well known that in the presence of electric field \((E_0)\) along x-axis and the quantizing magnetic field \((B)\) along z-axis, the DRs of carriers in semiconductors become modified, for which the carrier moves in both the z and y directions respectively. The motion along y direction is purely due to the presence of \(E_0\) along x-axis and in the absence of an electric field, the effective electron mass along y-axis tends to infinity indicating the fact that the electron motion along y-axis is forbidden. The effective electron mass of the isotropic, bulk semiconductors having parabolic energy bands exhibit mass anisotropy in the presence of cross-fields and this anisotropy depends on the electron energy, the magnetic quantum number, the electric and the magnetic fields respectively, although the effective electron mass along z-axis is a constant quantity. In 1966, Zawadzki and Lax [68] derived the expression of DR for III–V semiconductors in accordance with the two-band model of Kane under cross-fields configuration, which generates the interest to study this particular topic of solid-state science in general [69].

It is well known that heavy doping and carrier degeneracy are the keys to unlock the important properties of semiconductors; they are especially instrumental in dictating the characteristics of Ohmic and Schottky contacts respectively [70]. It is an amazing fact that although heavily doped semiconductors (HDS) have been investigated in the literature, the study of the corresponding DRs of HDS is still one of the open research problems. We have obtained the exact E-k dispersion
relations in HD nonlinear optical, III–V, II–VI, gallium phosphide, germanium, platinum antimonide, stressed, IV–VI, lead germanium telluride, tellurium, II–V, zinc and cadmium di-phosphides, bismuth telluride, III–V, II–VI, IV–VI and HgTe/CdTe quantum well HD superlattices with graded interfaces under magnetic quantization, III–V, II–VI, IV–VI and HgTe/CdTe HD effective mass superlattices under magnetic quantization, quantum confined effective mass superlattices and superlattices of HD optoelectronic materials with graded interfaces respectively. Our method is not related to the DOS technique as used in the aforementioned works. From the electron energy spectrum, one can obtain the DOS but the DOS technique, as used in the literature, cannot generate the DRs. Therefore, our study is more fundamental than those in the existing literature, because the Boltzmann transport equation, which controls the study of the charge transport properties of semiconductor devices, can be solved if and only if the DR is known.

This book is divided into five parts, each containing 1, 11, 5, 1 and 3 chapters, respectively; it is partially based on our ongoing research on the DR in HDS from 1974 and an attempt has been made to present a cross section of the DR for a wide range of HDS and their quantized-structures with varying carrier energy spectra under various physical conditions. It may be noted that among the 21 chapters of this book, two-third of the portion is new, whereas the remaining one-third is based on our previous eight books from Springer with necessary modifications in a condensed way not only for the larger cross section of readers and potential buyers to enjoy, but also to satisfy the self-consistent and sufficient conditions of Mathematics. The single chapter in Part I deals with DRs in HD Quantum Wells (QWs), NWs and QDs, respectively, in the presence of surface magnetic field. In Chap. 1 we study the DR in heavily doped QWs, NWs and QDs of HD III–V, ternary, quaternary materials and IV–VI semiconductors in the presence of surface magnetic field, respectively, on the basis of newly formulated electron energy spectra. We also investigate the same in the presence of cross-fields. This chapter explores the study of DR in cylindrical QD of HD III–V semiconductors in the presence of crossed electric and magnetic fields and in the presence of arbitrarily oriented magnetic field in QWs of HD III–V materials respectively. It is important to note that the surface magnetic field applied parallel to the surface makes effective carrier mass quantum number dependent, whose contribution to the oscillatory mobility would be important.

Part II deals with the influence of quantum confinement on the DR of non-parabolic HDS and in Chap. 2 we study the DR in UFs of HD nonlinear optical materials on the basis of a generalized electron dispersion law introducing the anisotropies of the effective masses and the spin orbit splitting constants, respectively, together with the inclusion of the crystal field splitting within the framework of the $k\cdot p$ formalism. We observe that the complex electron dispersion law in HDS instead of the real one occurs from the existence of the essential poles in the corresponding electron energy spectrum in the absence of band tails. The physical picture behind the existence of the complex energy spectrum in heavily doped nonlinear optical semiconductors is the interaction of the impurity atoms in
the tails with the splitting constants of the valance bands. The more the interaction, the more the prominence of the complex part than the other case. In the absence of band tails, there is no interaction of impurity atoms in the tails with the spin orbit constants and, consequently, the complex part vanishes. One important consequence of the HDS forming band tails is that **the effective mass exists in the forbidden zone, which is impossible without the effect of band tailing.** In the absence of band tails, **the effective mass in the band gap of semiconductors is infinity.** Besides, depending on the type of unperturbed carrier energy spectrum, **the new forbidden zone will appear within the normal energy band gap for HDS.**

The results of HD III–V (e.g. InAs, InSb, GaAs, etc.), ternary (e.g. Hg$_{1-x}$Cd$_x$Te), quaternary (e.g. In$_{1-x}$Ga$_x$As$_{1-y}$P$_y$ lattice matched to InP) compounds form a special case of our generalized analysis under certain limiting conditions. The DR in HD UFss of II–VI, IV–VI, stressed Kane type semiconductors, Te, GaP, PtSb$_2$, Bi$_2$Te$_3$, Ge, GaSb, II–V, lead germanium telluride, zinc and cadmium diphosphides has also been investigated in the appropriate sections. The importance of the aforementioned semiconductors has also been described in the same chapter. In the absence of band tails together with certain limiting conditions, all the results for all the DRs for all the HD UFss of Chap. 1 get simplified into the form of isotropic parabolic energy bands exhibiting the necessary mathematical compatibility test. In Chaps. 3 and 4, the DR for nanowires (NWs) and quantum dots (QDs) of all the materials of Chap. 2 have respectively been investigated. As a collateral study, we observe that the EEM in such QWs and NWs become a function of size quantum number, the Fermi energy, the scattering potential and other constants of the system, which is the intrinsic property of such 2D and 1D electrons.

With the advent of modern experimental techniques of fabricating nanomaterials as already noted, it is also possible to grow semiconductor superlattices (SLs) composed of alternative layers of two different degenerate layers with controlled thickness [71]. These structures have found wide applications in many new devices such as photodiodes [56], photoresistors [72], transistors [73], light emitters [74], tunneling devices [75], and others [76–88]. The investigations of the physical properties of narrow gap SLs have increased extensively since they are important for optoelectronic devices and because the quality of heterostructures involving narrow gap materials has been improved. It may be written in this context that doping superlattices are crystals with a periodic sequence of ultrathin film layers [89, 90] of the same semiconductor with the intrinsic layer in between, together with the opposite sign of doping. All the donors will be positively charged and all the acceptors negatively. This periodic space charge causes a periodic space charge potential which quantizes the motions of the carriers in the z direction together with the formation of sub-band energies. In Chap. 5, the DR in doping superlattices of HD nonlinear optical, III–V, II–VI, IV–VI, and stressed Kane type semiconductors has been investigated. In this case we note that the EEM in such doping supper lattices becomes a function of nipi sub-band index, surface electron concentration, Fermi energy, the scattering potential and other constants of the system, which is the intrinsic property of such 2D quantized systems.
It is well known that the electrons in bulk semiconductors in general have three-dimensional freedom of motion. When these electrons are confined in a one-dimensional potential well, whose width is of the order of the carrier wavelength, the motion in that particular direction gets quantized while that along the other two directions remains free. Thus, the energy spectrum appears in the shape of discrete levels for one-dimensional quantization, each of which has a continuum for two-dimensional free motion. The transport phenomena of such one-dimensional confined carriers have recently been studied [7.1–7.20] with great interest. For the metal-oxide-semiconductor (MOS) structures, the work functions of the metal and the semiconductor substrate are different and the application of an external voltage at the metal-gate causes the change in charge density at the oxide semiconductor interface leading to a bending of the energy bands of the semiconductor near the surface. As a result, a one-dimensional potential well is formed at the semiconductor interface. The spatial variation of the potential profile is so sharp that for considerably large values of the electric field, the width of the potential well becomes of the order of the de Broglie wavelength of the carriers. The Fermi energy, which is near the edge of the conduction band in the bulk, becomes nearer to the edge of the valance band at the surface creating inversion layers. The energy levels of the carriers bound within the potential well get quantized and form electric sub bands. Each sub band corresponds to a quantized level in a plane perpendicular to the surface leading to a quasi two-dimensional electron gas. Thus, the extreme band bending at low temperature allows us to observe the quantum effects at the surface [91]. Although considerable work has already been done regarding the various physical properties of different types of inversion layers having various band structures, nevertheless it appears from the literature that there lies scope in the investigations made while the interest for studying different other features of accumulation layers is becoming increasingly important. In Chap. 6, the DR in accumulation layers of HD nonlinear optical, III–V, II–VI, IV–VI, stressed Kane type semiconductors and Ge have been investigated. For the purpose of relative comparisons, we have also studied the DR in inversion layers of the aforementioned materials. It is interesting to note that the EEM in such layers is a function of electric sub-band index, surface electric field, Fermi energy, scattering potential and other constants of the system, which is the intrinsic property of such 2D electrons.

It is worth remarking that the effects of quantizing magnetic field (B) on the band structures of compound semiconductors are more striking than those of the parabolic one and are easily observed in experiments. A number of interesting physical features originate from the significant changes in the basic energy wave vector relation of the carriers caused by the magnetic field. Valuable information could also be obtained from experiments under magnetic quantization regarding important physical properties such as Fermi energy and effective masses of the carriers, which affect almost all the transport properties of the electron devices [92] of various materials having different carrier dispersion relations [93, 94].

Specifically, in Chap. 7 we study the DR in HD nonlinear optical materials in the presence of magnetic quantization. The results of HD III–V (e.g. InAs, InSb, GaAs
etc.), ternary (e.g. Hg$_{1-x}$Cd$_x$Te), quaternary (e.g. In$_{1-x}$Ga$_x$As$_{1-y}$P$_y$ lattice matched to InP) compounds form a special case of our generalized analysis under certain limiting conditions. The magneto DR for HD II–VI, IV–VI, stressed Kane type semiconductors, Te, GaP, PtSb$_2$, Bi$_2$Te$_3$, Ge, GaSb, II–V and lead germanium telluride has also been investigated by formulating the respective appropriate HD energy band structure. In the absence of band tails, together with certain limiting conditions, all the results for all the DRs for all the HD compounds as considered in this chapter get simplified into the well-known parabolic energy bands under magnetic quantization exhibiting the necessary mathematical compatibility test.

Chapter 8 investigates the DR under cross-field configuration in HD nonlinear optical, III–V, II–VI, IV–VI and stressed Kane type semiconductors respectively. This chapter also tells us that the EEM in all the cases is a function of the finite scattering potential, the magnetic quantum number, the electric field, the quantizing magnetic field and the Fermi energy even for HD semiconductors, whose bulk electrons in the absence of band tails are defined by the parabolic energy bands. In Chap. 9 the DR in HDs of non-parabolic semiconductors under magneto-size quantization has been studied for all the materials of Chap. 7. In Chap. 10 the DR in HD ultrathin films under cross-fields configuration has been investigated for all the materials of Chap. 8. In Chap. 11 the magneto DR in doping superlattices has been investigated for all the cases of Chap. 5. The magneto DR in accumulation and inversion layers has been explored in Chap. 12 for all the case of Chap. 6.

In Part III we study the DRs in quantum confined superlattices (SLs). It is well known that Keldysh [95] first suggested the fundamental concept of a SL, although it was successfully experimentally realized by Esaki and Tsu [96]. The importance of SLs in the field of nanoelectronics has already been described in [97–99]. The most extensively studied III–V SL is that consisting of alternate layers of GaAs and Ga$_{1-x}$Al$_x$As owing to the relative ease of fabrication. The GaAs layer forms quantum wells and Ga$_{1-x}$Al$_x$As form potential barriers. The III–V SLs are attractive for the realization of high speed electronic and optoelectronic devices [100]. In addition to SLs of the usual structure, SLs with more complex structures such as II–VI [101], IV–VI [102] and HgTe/CdTe [103] SLs have also been proposed. The IV–VI SLs exhibit quite different properties compared to the III–V SL due to the peculiar band structure of the constituent materials [104]. The epitaxial growth of II–VI SL is a relatively recent development and the primary motivation for studying the mentioned SLs made of materials with large band gap is in their potential for optoelectronic operation in the blue [104]. HgTe/CdTe SLs have raised a great deal of attention since 1979 as a promising new material for long wavelength infrared detectors and other electro-optical applications [105]. Interest in Hg-based SLs further increased as new properties with potential device applications were revealed [106]. These features arise from the unique zero band gap material HgTe [107] and the direct band gap semiconductor CdTe, which can be described by the three-band mode of Kane [108]. The combination of the aforementioned materials with specified dispersion relation makes HgTe/CdTe SL very attractive, especially because of the possibility to tailor the material properties for various applications by
varying the energy band constants of the SLs. In addition, for effective mass SLs, the electronic sub-bands appear continually in real space [109].

We note that all the aforementioned SLs have been proposed with the assumption that the interfaces between the layers are sharply defined, of zero thickness, i.e., devoid of any interface effects. The SL potential distribution may be then considered as a one-dimensional array of rectangular potential wells. The aforementioned advanced experimental techniques may produce SLs with physical interfaces between the two materials crystallographically abrupt; adjoining their interface will change at least on an atomic scale. As the potential form changes from a well (barrier) to a barrier (well), an intermediate potential region exists for the electrons. The influence of finite thickness of the interfaces on the electron dispersion law is very important, since the electron energy spectrum governs the electron transport in SLs.

In Chap. 13 the DR in III–V, II–VI, IV–VI, HgTe/CdTe and strained layer quantum well heavily doped superlattices (QWHDSLs) with graded interfaces is studied. Besides, the DR in III–V, II–VI, IV–VI, HgTe/CdTe and strained layer quantum well HD effective mass superlattices, respectively, has also been explored. In Chaps. 14 and 15 the DRs in quantum wire HD superlattices and quantum dot HD superlattices have, respectively, been investigated for all the cases of Chap. 13. Chapter 16 contains the study of the DR in HD SLs under magnetic quantization for all the cases of Chap. 13. In the last Chap. 17 of Part III, we have studied the DR in quantum well HD superlattices under magnetic quantization for all the cases of Chap. 13.

With the advent of nanophotonics, there has been considerable interest in studying the optical processes in semiconductors and their nanostructures in the presence of intense light waves [110]. It appears from the literature that the investigations in the presence of external intense photo-excitation have been carried out on the assumption that the carrier energy spectra are invariant quantities under strong external light waves, which is not fundamentally true. The physical properties of semiconductors in the presence of strong light waves which alter the basic dispersion relations have relatively been much less investigated in [111, 112] as compared with the cases of other external fields and in opto-electronics the influence of strong light waves is needed for the characterization of low-dimensional opto-electronic devices. The solo Chap. 18 of Part IV investigates the DR in bulk specimens HD Kane type semiconductors under intense light waves. The same chapter studies DR in the presence of magnetic quantization, cross-fields configuration, QWs, NWs, QDs, magneto size quantization, inversion and accumulation layers, magneto inversion and magneto accumulation layers, doping superlattices, magneto doping superlattices, QWHD, NWHD and QDHD effective mass superlattices, magneto QWHD effective mass superlattices, magneto HD effective mass superlattices, QWHD, NWHD and QDHD superlattices with graded interfaces, magneto QWHD superlattices with graded interfaces and magneto HD superlattices with graded interfaces respectively.

With the advent of nanodevices, the built-in electric field becomes so large that the electron energy spectrum changes fundamentally [113–115] instead of being invariant and Chap. 19 of Part V of this book investigates the DR under intense
electric field in bulk specimens of HD III–V, ternary and quaternary semiconductors. The same chapter also explores the influence of electric field on the DR in the presence of magnetic quantization, cross-fields configuration, QWs, NWs, QDs, magneto size quantum effect, inversion and accumulation layers, magneto inversion and magneto accumulation layers, doping superlattices, magneto doping superlattices, QWHD, NWHD and QDHD effective mass superlattices, magneto QWHD effective mass superlattices, magneto HD effective mass superlattices, QWHD, NWHD and QDHD superlattices with graded interfaces, magneto QWHD superlattices with graded interfaces and magneto HD superlattices with graded interfaces and, respectively, magnetic quantization, size quantization, accumulation layers, HD doping superlattices and effective mass HD superlattices under magnetic quantization respectively. It is interesting to note that the EEM depends on the strong electric field (which is not observed elsewhere) together with the fact that the EEM in the said systems depends on the respective quantum numbers in addition to the Fermi energy, the scattering potential and others system constants which are the characteristics features of such heterostructures.

Chapter 20 explores 28 different applications, namely Carrier Statistics, ThermoElectric Power, Debye Screening Length, Carrier contribution to the elastic constants, Diffusivity-mobility ratio, Measurement of Band-gap in the presence of Light Waves, Diffusion coefficient of the minority carriers, Nonlinear optical response, Third order nonlinear optical susceptibility, Generalized Raman gain, The plasma frequency, The activity coefficient, Magneto-Thermal effect in Quantized Structures, Normalized Hall coefficient, Reflection coefficient, Heat Capacity, Magnetic Susceptibilities, Faraday rotation, Fowler-NordheimFied Emission, Optical Effective Mass, Einstein’s Photoemission, Righi-Leduc coefficient, Electric Susceptibility, Electric Susceptibility Mass, Electron Diffusion Thermo-power, Hydrostatic Piezo-resistance Coefficient, Relaxation time for Acoustic Mode Scattering and Gate Capacitance of the content of this book and Chap. 21 contains the conclusions and future research. It is needless to say that this monograph is based on the ‘iceberg principle’ [116] and the rest of it will be explored by researchers from different appropriate fields. Since there is no existing report devoted solely to the study of DR for HD quantized structures to the best of our knowledge, we earnestly hope that the present book will a useful reference source for the present and the next generation of readers and researchers of materials and allied sciences in general. We have discussed enough regarding DRs in different quantized HD materials although a number of new computer-oriented numerical analyses are being left for the purpose of being computed by the readers, to generate the new graphs and the inferences from them which altogether is a sea by itself. Since the production of an error-free first edition of any book from every point of view is a permanent member of impossibility theorems, therefore in spite of our joint concentrated efforts for a couple of years together with the seasoned team of Springer, the same stands very true for this monograph also. Various expressions and a few chapters of this book are appearing for the first time in printed form. Suggestions from the readers for the improvement of the book will be highly appreciated for the purpose of inclusion in future editions, if any. In this book, from
the first chapter till the end, we have presented 200 open research problems for graduate students, PhD aspirants, researchers and engineers in this pinpointed research topic. We strongly hope that alert readers of this monograph will not only solve the said problems by removing all the mathematical approximations and establishing the appropriate uniqueness conditions, but will also generate new research problems both theoretical and experimental and, thereby, transform this monograph into a solid book. Incidentally, our readers after reading this book will easily understand how little is presented and how much more is yet to be investigated on this exciting topic, which is the signature of coexistence of new physics and advanced mathematics combined with the inner fire for performing creative researches in this context by young scientists, as like Kikoin [117] we feel that “A young scientist is no good if his teacher learns nothing from him and gives his teacher nothing to be proud of”. We emphatically assert that the problems presented here form an integral part of this book and will be useful for readers to initiate their own contributions on the DR for HDS and their quantized counterparts. Like Sakurai [118], we firmly believe “The reader who has read the book but cannot do the exercise has learned nothing”. It is nice to note that if we assign the alphabets A–Z, the positive integers from 1 to 26 chronologically, then the word “ATTITUDE” receives the perfect score 100 and is the vital quality needed from the readers since attitude is the ladder on which all other virtues mount.

In this monograph, we have investigated the expressions of effective electron mass and the sub-band energy has been formulated throughout this monograph as a collateral study for the purpose of in-depth investigations of the mentioned important pinpointed research topics. Thus, in this book, the readers will get much information regarding the influence of quantization in HD low-dimensional materials having different band structures. Although the name of the book is an example of extremely high Q-factor, from the content one can easily infer that it should be useful for graduate courses on materials science, condensed matter physics, solid-state electronics, nanoscience and technology and solid-state sciences and devices in many universities and the institutions in addition to both Ph.D. students and researchers in the aforementioned fields. Last but not the least, the author hopes that his humble effort will kindle the desire to delve deeper into this fascinating and deep topic by anyone engaged in materials research and device development either in academics or in industries.

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