

5. Normal Modes of a Three-Dimensional Crystal

Consider a face-centered cubic monatomic Bravais lattice in which each ion interacts only with its (twelve) nearest neighbors. Assume that the interaction between a pair of neighboring ions is described by a pair potential ϕ that depends only on the distance r between the pair of ions.

(a) Show that the frequencies of the three normal modes with wave vector \mathbf{k} are given by

$$\omega = \sqrt{\lambda/M} \quad (22.96)$$

where the λ are the eigenvalues of the 3×3 matrix:

$$\mathbf{D} = \sum_{\mathbf{R}} \sin^2 \left(\frac{1}{2} \mathbf{k} \cdot \mathbf{R} \right) [A \mathbf{1} + B \hat{\mathbf{R}} \hat{\mathbf{R}}]. \quad (22.97)$$

Here the sum is over the twelve nearest neighbors of $\mathbf{R} = 0$:

$$\frac{a}{2} (\pm \hat{x} \pm \hat{y}), \quad \frac{a}{2} (\pm \hat{y} \pm \hat{z}), \quad \frac{a}{2} (\pm \hat{z} \pm \hat{x}); \quad (22.98)$$

$\mathbf{1}$ is the unit matrix ($(\mathbf{1})_{\mu\nu} = \delta_{\mu\nu}$), and $\hat{\mathbf{R}} \hat{\mathbf{R}}$ is the diadic formed from the unit vectors $\hat{\mathbf{R}} = \mathbf{R}/R$ (i.e., $(\hat{\mathbf{R}} \hat{\mathbf{R}})_{\mu\nu} = \hat{\mathbf{R}}_\mu \hat{\mathbf{R}}_\nu$). The constants A and B are: $A = 2\phi(d)/d$, $B = 2[\phi''(d) - \phi'(d)/d]$, where d is the equilibrium nearest-neighbor distance. (This follows from Equations (22.59) and (22.11).)

(b) Show that when \mathbf{k} is in the (100) direction ($\mathbf{k} = (k, 0, 0)$ in rectangular coordinates), then one normal mode is strictly longitudinal, with frequency

$$\omega_L = \sqrt{\frac{8A + 4B}{M}} \sin \frac{1}{4}ka, \quad (22.99)$$

and the other two are strictly transverse and degenerate, with frequency

$$\omega_T = \sqrt{\frac{8A + 2B}{M}} \sin \frac{1}{4}ka. \quad (22.100)$$

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Simulations for Solid State Physics Hardback with CD-ROM Robert H. Silsbee, Joerg Draeger, Jörg Dräger, 1997-06-28

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The Specific Heat Of Matter At Low Temperatures Ahmet Tari, 2003-08-12 Recent discoveries of new materials and improvements in calorimetric techniques have given new impetus to the subject of specific heat Nevertheless there is a serious lack of literature on the subject This invaluable book which goes some way towards remedying that is concerned mainly with the specific heat of matter at ordinary temperatures It discusses the principles that underlie the theory of specific heat and considers a number of theoretical models in some detail The subject matter ranges from traditional materials to those recently discovered heavy fermion compounds high temperature superconductors spin glasses and so on and includes a large number of figures tables and references The book will be particularly useful for advanced undergraduate and postgraduate students as well as academics and researchers a

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Nano-Electronic Devices Dragica Vasileska,Stephen M. Goodnick,2011-06-10 This book surveys the advanced simulation methods needed for proper modeling of state of the art nanoscale devices It systematically describes theoretical approaches and the numerical solutions that are used in explaining the operation of both power devices as well as nano scale devices It clearly explains for what types of devices a particular method is suitable which is the most critical point that a researcher faces and has to decide upon when modeling semiconductor devices

Meeting Abstracts Electrochemical Society. Meeting,1999 *Understanding Solid State Physics* Jacques Cazaux,2016-03-23 The correlation between the microscopic composition of solids and their macroscopic electrical optical thermal properties is the goal of solid state physics This book is the deeply revised version of the French book Initiation a physique du solide exercices commentes avec rappels de cours written more than 20 years ago It has five sections

An Experimental and Theoretical Study of Furan Decomposition on Pd(111) Using Scanning Tunneling Microscopy and Density

Functional Theory Albert Loui,2005 **Ferroelectricity in Doped Hafnium Oxide** Uwe Schroeder,Cheol Seong Hwang,Hiroshi Funakubo,2019-03-27 Ferroelectricity in Doped Hafnium Oxide Materials Properties and Devices covers all aspects relating to the structural and electrical properties of HfO₂ and its implementation into semiconductor devices including a comparison to standard ferroelectric materials The ferroelectric and field induced ferroelectric properties of HfO₂ based films are considered promising for various applications including non volatile memories negative capacitance field effect transistors energy storage harvesting and solid state cooling Fundamentals of ferroelectric and piezoelectric properties HfO₂ processes and the impact of dopants on ferroelectric properties are also extensively discussed in the book along with phase transition switching kinetics epitaxial growth thickness scaling and more Additional chapters consider the modeling of ferroelectric phase transformation structural characterization and the differences and similarities between HfO₂ and standard ferroelectric materials Finally HfO₂ based devices are summarized Explores all aspects of the structural and electrical properties of HfO₂ including processes modelling and implementation into semiconductor devices Considers potential applications including FeCaps FeFETs NCFETs FTJs and more Provides comparison of an emerging ferroelectric material to conventional ferroelectric materials with insights to the problems of downscaling that conventional ferroelectrics

face *Whitaker's Books in Print*, 1998 *Soviet Electrochemistry*, 1984 *Helium Three* W. P. Halperin, Lev Petrovich Pitaevskii, 1990 Introducing the subject of superfluid helium three and polarized liquid helium three this book is devoted to modern problems in many body physics specific to the quantum fluid helium three Relationships between properties of helium three and topics in other fields are established including superconductivity non linear dynamics acoustics and magnetically polarized quantum systems Among the chapters in this collection one finds valuable reference material and original research not published elsewhere Advanced research topics are presented in a pedagogical manner in considerable depth and with appropriate introductory material sufficiently general to be suitable to the non specialist **British Books in Print**, 1979 **Microdosimetry** H. G. Menzel, 1994 **Studies of Phase Transitions and Critical Phenomena** Raymond Ethan Goldstein, 1988 **Subject Guide to Books in Print**, 1975

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