

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:

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

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., $(\hat{\mathbf{R}}\hat{\mathbf{R}})_{\mu\nu} = \hat{R}_\mu\hat{R}_\nu$). 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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Judd E. Hollander



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Problems In Solid State Physics With Solutions Fuxiang Han, 2011-10-31 This book provides a practical approach to consolidate one's acquired knowledge or to learn new concepts in solid state physics through solving problems. It contains 300 problems on various subjects of solid state physics. The problems in this book can be used as homework assignments in an introductory or advanced course on solid state physics for undergraduate or graduate students. It can also serve as a desirable reference book to solve typical problems and grasp mathematical techniques in solid state physics. In practice it is more fascinating and rewarding to learn a new idea or technique through solving challenging problems rather than through reading only. In this aspect this book is not a plain collection of problems but it presents a large number of problem solving ideas and procedures some of which are valuable to practitioners in condensed matter physics.

Princeton Problems in Physics with Solutions Nathan Newbury, Mark Newman, 2015-03-25 Aimed at helping the physics student to develop a solid grasp of basic graduate level material this book presents worked solutions to a wide range of informative problems. These problems have been culled from the preliminary and general examinations created by the physics department at Princeton University for its graduate program. The authors all students who have successfully completed the examinations selected these problems on the basis of usefulness, interest and originality and have provided highly detailed solutions to each one. Their book will be a valuable resource not only to other students but to college physics teachers as well. The first four chapters pose problems in the areas of mechanics, electricity and magnetism, quantum mechanics and thermodynamics and statistical mechanics thereby serving as a review of material typically covered in undergraduate courses. Later chapters deal with material new to most first year graduate students challenging them on such topics as condensed matter, relativity and astrophysics, nuclear physics, elementary particles and atomic and general physics.

Solid State Physics László Mihály, Michael C Martin, 2009-02-24 The ideal companion in condensed matter physics now in new and revised edition. Solving homework problems is the single most effective way for students to familiarize themselves with the language and details of solid state physics. Testing problem solving ability is the best means at the professor's disposal for measuring student progress at critical points in the learning process. This book enables any instructor to supplement end of chapter textbook assignments with a large number of challenging and engaging practice problems and discover a host of new ideas for creating exam questions. Designed to be used in tandem with any of the excellent textbooks on this subject, *Solid State Physics Problems and Solutions* provides a self study approach through which advanced undergraduate and first year graduate students can develop and test their skills while acclimating themselves to the demands of the discipline. Each problem has been chosen for its ability to illustrate key concepts, properties and systems knowledge of which is crucial in developing a complete understanding of the subject including Crystals, diffraction and reciprocal lattices, Phonon dispersion and electronic band structure, Density of states, Transport, magnetic and optical properties, Interacting electron systems.

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Table of Contents Ashcroft Mermin Problem 5 Solution

1. Understanding the eBook Ashcroft Mermin Problem 5 Solution
 - The Rise of Digital Reading Ashcroft Mermin Problem 5 Solution
 - Advantages of eBooks Over Traditional Books
2. Identifying Ashcroft Mermin Problem 5 Solution
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Ashcroft Mermin Problem 5 Solution
 - User-Friendly Interface
4. Exploring eBook Recommendations from Ashcroft Mermin Problem 5 Solution
 - Personalized Recommendations
 - Ashcroft Mermin Problem 5 Solution User Reviews and Ratings
 - Ashcroft Mermin Problem 5 Solution and Bestseller Lists
5. Accessing Ashcroft Mermin Problem 5 Solution Free and Paid eBooks
 - Ashcroft Mermin Problem 5 Solution Public Domain eBooks
 - Ashcroft Mermin Problem 5 Solution eBook Subscription Services
 - Ashcroft Mermin Problem 5 Solution Budget-Friendly Options
6. Navigating Ashcroft Mermin Problem 5 Solution eBook Formats

- ePub, PDF, MOBI, and More
- Ashcroft Mermin Problem 5 Solution Compatibility with Devices
- Ashcroft Mermin Problem 5 Solution Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Ashcroft Mermin Problem 5 Solution
 - Highlighting and Note-Taking Ashcroft Mermin Problem 5 Solution
 - Interactive Elements Ashcroft Mermin Problem 5 Solution
- 8. Staying Engaged with Ashcroft Mermin Problem 5 Solution
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Ashcroft Mermin Problem 5 Solution
- 9. Balancing eBooks and Physical Books Ashcroft Mermin Problem 5 Solution
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Ashcroft Mermin Problem 5 Solution
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Ashcroft Mermin Problem 5 Solution
 - Setting Reading Goals Ashcroft Mermin Problem 5 Solution
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Ashcroft Mermin Problem 5 Solution
 - Fact-Checking eBook Content of Ashcroft Mermin Problem 5 Solution
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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