

## Contents

### Prefaces IX

#### Part 1 Introduction 1

#### 0 Geometry of Crystal Lattice 3

- 0.1 Translational Symmetry 3
- 0.2 Bravais Lattice 5
- 0.3 The Reciprocal Lattice 7
- 0.4 Use of Penetrating Radiation to Determine Crystal Structure 10
  - 0.4.1 Problems 12

#### Part 2 Classical Dynamics of a Crystal Lattice 15

#### 1 Mechanics of a One-Dimensional Crystal 17

- 1.1 Equations of Motion and Dispersion Law 17
  - 1.1.1 Problems 23
- 1.2 Motion of a Localized Excitation in a Monatomic Chain 24
- 1.3 Transverse Vibrations of a Linear Chain 29
- 1.4 Solitons of Bending Vibrations of a Linear Chain 33
- 1.5 Dynamics of Biatomic 1D Crystals 36
- 1.6 Frenkel–Kontorova Model and sine-Gordon Equation 39
- 1.7 Soliton as a Particle in 1D Crystals 43
- 1.8 Harmonic Vibrations in a 1D Crystal Containing a Crowdion (Kink) 46
- 1.9 Motion of the Crowdion in a Discrete Chain 49
- 1.10 Point Defect in the 1D Crystal 51
- 1.11 Heavy Defects and 1D Superlattice 54

#### 2 General Analysis of Vibrations of Monatomic Lattices 59

- 2.1 Equation of Small Vibrations of 3D Lattice 59

2.2	The Dispersion Law of Stationary Vibrations	63
2.3	Normal Modes of Vibrations	66
2.4	Analysis of the Dispersion Law	67
2.5	Spectrum of Quasi-Wave Vector Values	70
2.6	Normal Coordinates of Crystal Vibrations	72
2.7	The Crystal as a Violation of Space Symmetry	74
2.8	Long-Wave Approximation and Macroscopic Equations for the Displacements Field	75
2.9	The Theory of Elasticity	77
2.10	Vibrations of a Strongly Anisotropic Crystal (Scalar Model)	80
2.11	“Bending” Waves in a Strongly Anisotropic Crystal	83
2.11.1	Problem	88
<b>3</b>	<b>Vibrations of Polyatomic Lattices</b>	<b>89</b>
3.1	Optical Vibrations	89
3.2	General Analysis of Vibrations of Polyatomic Lattice	94
3.3	Molecular Crystals	98
3.4	Two-Dimensional Dipole Lattice	101
3.5	Optical Vibrations of a 2D Lattice of Bubbles	105
3.6	Long-Wave Librational Vibrations of a 2D Dipole Lattice	109
3.7	Longitudinal Vibrations of 2D Electron Crystal	112
3.8	Long-Wave Vibrations of an Ion Crystal	117
3.8.1	Problems	123
<b>4</b>	<b>Frequency Spectrum and Its Connection with the Green Function</b>	<b>125</b>
4.1	Constant-Frequency Surface	125
4.2	Frequency Spectrum of Vibrations	129
4.3	Analysis of Vibrational Frequency Distribution	132
4.4	Dependence of Frequency Distribution on Crystal Dimensionality	136
4.5	Green Function for the Vibration Equation	141
4.6	Retarding and Advancing Green Functions	145
4.7	Relation Between Density of States and Green Function	147
4.8	The Spectrum of Eigenfrequencies and the Green Function of a Deformed Crystal	149
4.8.1	Problems	151
<b>5</b>	<b>Acoustics of Elastic Superlattices: Phonon Crystals</b>	<b>153</b>
5.1	Forbidden Areas of Frequencies and Specific Dynamic States in such Areas	153
5.2	Acoustics of Elastic Superlattices	155
5.3	Dispersion Relation for a Simple Superlattice Model	159
5.3.1	Problem	162

<b>Part 3</b>	<b>Quantum Mechanics of Crystals</b>	<b>163</b>
<b>6</b>	<b>Quantization of Crystal Vibrations</b>	<b>165</b>
6.1	Occupation-Number Representation	165
6.2	Phonons	170
6.3	Quantum-Mechanical Definition of the Green Function	172
6.4	Displacement Correlator and the Mean Square of Atomic Displacement	174
6.5	Atomic Localization near the Crystal Lattice Site	176
6.6	Quantization of Elastic Deformation Field	178
<b>7</b>	<b>Interaction of Excitations in a Crystal</b>	<b>183</b>
7.1	Anharmonicity of Crystal Vibrations and Phonon Interaction	183
7.2	The Effective Hamiltonian for Phonon Interaction and Decay Processes	186
7.3	Inelastic Diffraction on a Crystal and Reproduction of the Vibration Dispersion Law	191
7.4	Effect of Thermal Atomic Motion on Elastic $\gamma$ -Quantum-Scattering	196
7.5	Equation of Phonon Motion in a Deformed Crystal	198
<b>8</b>	<b>Quantum Crystals</b>	<b>203</b>
8.1	Stability Condition of a Crystal State	203
8.2	The Ground State of Quantum Crystal	206
8.3	Equations for Small Vibrations of a Quantum Crystal	207
8.4	The Long-Wave Vibration Spectrum	211
<b>Part 4</b>	<b>Crystal Lattice Defects</b>	<b>213</b>
<b>9</b>	<b>Point Defects</b>	<b>215</b>
9.1	Point-Defect Models in the Crystal Lattice	215
9.2	Defects in Quantum Crystals	218
9.3	Mechanisms of Classical Diffusion and Quantum Diffusion of Defectons	222
9.4	Quantum Crowdion Motion	225
9.5	Point Defect in Elasticity Theory	227
9.5.1	Problem	232
<b>10</b>	<b>Linear Crystal Defects</b>	<b>233</b>
10.1	Dislocations	233
10.2	Dislocations in Elasticity Theory	235
10.3	Glide and Climb of a Dislocation	238
10.4	Disclinations	241
10.5	Disclinations and Dislocations	244
10.5.1	Problems	246

<b>11</b>	<b>Localization of Vibrations</b>	<b>247</b>
11.1	Localization of Vibrations near an Isolated Isotope Defect	247
11.2	Elastic Wave Scattering by Point Defects	253
11.3	Green Function for a Crystal with Point Defects	259
11.4	Influence of Defects on the Density of Vibrational States in a Crystal	264
11.5	Quasi-Local Vibrations	267
11.6	Collective Excitations in a Crystal with Heavy Impurities	271
11.7	Possible Rearrangement of the Spectrum of Long-Wave Crystal Vibrations	274
11.7.1	Problems	277
<b>12</b>	<b>Localization of Vibrations Near Extended Defects</b>	<b>279</b>
12.1	Crystal Vibrations with 1D Local Inhomogeneity	279
12.2	Quasi-Local Vibrations Near a Dislocation	283
12.3	Localization of Small Vibrations in the Elastic Field of a Screw Dislocation	285
12.4	Frequency of Local Vibrations in the Presence of a Two-Dimensional (Planar) Defect	288
<b>13</b>	<b>Elastic Field of Dislocations in a Crystal</b>	<b>297</b>
13.1	Equilibrium Equation for an Elastic Medium Containing Dislocations	297
13.2	Stress Field Action on Dislocation	299
13.3	Fields and the Interaction of Straight Dislocations	303
13.4	The Peierls Model	309
13.5	Dislocation Field in a Sample of Finite Dimensions	312
13.6	Long-Range Order in a Dislocated Crystal	314
13.6.1	Problems	319
<b>14</b>	<b>Dislocation Dynamics</b>	<b>321</b>
14.1	Elastic Field of Moving Dislocations	321
14.2	Dislocations as Plasticity Carriers	325
14.3	Energy and Effective Mass of a Moving Dislocation	327
14.4	Equation for Dislocation Motion	331
14.5	Vibrations of a Lattice of Screw Dislocations	336
	<b>Bibliography</b>	<b>341</b>
	<b>Index</b>	<b>343</b>