

CONTENTS

CONTRIBUTORS	xv
FOREWORD	xvii
PREFACE	xviii
LIST OF VOLUMES IN TREATISE	xix
0. Introduction: Physical Description of Ultrasonic Fields by PETER D. EDMONDS AND F. DUNN	
0.1. Development of Propagation Relations	3
0.2. Reflection and Refraction	9
0.3. Absorption	20
0.3.1. Relaxation Processes	21
0.4. Attenuation.	27
1. Piezoelectric Transducers by MATTHEW O'DONNELL, L. J. BUSSE, AND J. G. MILLER	
1.1. Introduction	29
1.2. Physical Principles of Piezoelectricity	34
1.2.1. Piezoelectric Constitutive Relations	34
1.2.2. Propagation of Ultrasound in Piezoelectric Materials.	36
1.2.3. Piezoelectric Generation and Detection of Ultrasound.	37
1.3. Distributed and Lumped Element Equivalent Circuits .	40
1.3.1. Transmission Line Model	41
1.3.2. Mason Equivalent Circuit	44
1.3.3. KLM Equivalent Circuit	47

1.4. Design Considerations for Practical Devices	51
1.4.1. Material Properties	51
1.4.2. Practical Transducers	55
1.5. Concluding Remarks	65
 2. Ultrasonic Wave Velocity and Attenuation Measurements by M. A. BREAZEALE, JOHN H. CANTRELL, JR., AND JOSEPH S. HEYMAN	
2.1. Introduction	67
2.1.1. Sources of Error	68
2.2. Systems for Making Measurements	76
2.2.1. Optical Systems.	76
2.2.2. Pulse Systems	85
2.2.3. Continuous Wave Techniques	111
2.3. Conclusion	133
 3. Dynamic Viscosity Measurement by GILROY HARRISON AND A. JOHN BARLOW	
3.1. Introduction	138
3.2. Phenomenological Theory of Viscoelastic Liquids . . .	139
3.2.1. Plane Shear Wave Propagation in a Viscoelastic Liquid	139
3.2.2. The Creep Response	141
3.2.3. Relaxation and Retardation Spectra	143
3.2.4. Data Reduction: Time-Temperature/ Time-Pressure Superposition	144
3.3. Experimental Techniques	146
3.3.1. General Considerations	146
3.3.2. Reflection of Plane Shear Waves	148
3.3.3. Guided Traveling Waves	159
3.3.4. Resonance Techniques.	166
3.3.5. High-Pressure Techniques	170
3.4. Analysis and Interpretation of Results	172

4. Ultrasonic Chemical Relaxation Spectroscopy	
by LEON J. SLUTSKY	
4.1. General and Historical Introduction	181
4.1.1. Relaxation Spectroscopy, Thermodynamic Preliminaries	181
4.1.2. Acoustic Relaxation	186
4.2. Relaxation Amplitudes and the Magnitude of the Chemical Contribution to the Equation of State	195
4.2.1. The Variation of Equilibrium Chemical Composition with Temperature and Pressure	195
4.2.2. Chemical Contributions to the Heat Capacity, Coefficient of Thermal Expansion, and Adiabatic Compressibility	198
4.2.3. The Evaluation of Γ in a Nonideal System	201
4.3. Linearized Rate Equations	207
4.3.1. Rate Laws, Elementary Steps, Reaction Mechanisms	207
4.3.2. A Simple Example	208
4.3.3. Coupled Reactions	209
4.3.4. Redundant Reactions	211
4.3.5. A More General Formulation	212
4.4. Coupling with Transport and Irreversible Reactions	217
4.4.1. Coupling between Reaction and Diffusion	217
4.4.2. Reaction Far from Equilibrium	220
4.5. Interpretative Problems	222
4.5.1. A Straightforward Case	222
4.5.2. Ionization Reactions of <i>p</i> -Aminobenzoic Acid: Kinetic Models	225
4.5.3. Polymers and Other Complex Systems	229
5. Scattering in Polycrystalline Media	
by EMMANUEL P. PAPADAKIS	
5.1. Introduction	237
5.1.1. General Comments	237
5.1.2. Scope of the Part	239

5.2.	Attenuation Caused by Grain Scattering	240
5.2.1.	Theory of Grain Scattering	240
5.2.2.	Some Experimental Methods	257
5.2.3.	Experiments on Grain Scattering	267
5.3.	Difficulties to Be Encountered	291
5.3.1.	Anisotropy	291
5.3.2.	Specimens of Finite Width	294
5.4.	Summary	297
6.	Nonlinear Phenomena	
	by JAMES A. ROONEY	
6.0.	Introduction	299
6.1.	Nonlinear Propagation of Sound	299
6.1.1.	Introduction to the Theory	300
6.1.2.	Experimental Methods	301
6.1.3.	Parametric Array	302
6.2.	Radiation Force	303
6.2.1.	Introduction to the Theory	303
6.2.2.	Experimental Methods	305
6.2.3.	Calibration and Errors	309
6.2.4.	Novel Applications and Techniques	310
6.3.	Acoustic Manipulation of Objects	312
6.3.1.	Introduction	312
6.3.2.	Theory	313
6.3.3.	Experimental Arrangements	314
6.3.4.	Applications and Special Effects	316
6.4.	Acoustic Streaming	319
6.4.1.	Introduction	319
6.4.2.	Theory	319
6.4.3.	Experimental Production of Acoustic Streaming	321
6.4.4.	Methods for Study of Acoustic Streaming Patterns	324
6.4.5.	Novel Experimental Methods	326
6.4.6.	Use of Acoustic Streaming to Study Biological Structure and Function	327

6.5. Emulsification and Aggregate Dispersal	328
6.5.1. Introduction	328
6.5.2. Sonic Methods for Emulsification	328
6.5.3. Mechanisms and Efficiency of Emulsification. .	330
6.5.4. Dispersal of Biological Cell Aggregates	331
6.6. Atomization and Droplet Formation	333
6.6.1. Introduction	333
6.6.2. Methods for Ultrasonic Atomization	333
6.6.3. Investigation of Mechanisms for Ultrasonic Atomization	336
6.6.4. Droplet Production	338
6.7. Acoustic Agglomeration	340
6.7.1. Introduction	340
6.7.2. Experimental Approaches to the Study of Agglomeration	340
6.7.3. Mechanisms Relevant to Agglomeration	342
6.8. Acoustic Drying	342
6.8.1. Introduction	342
6.8.2. Experimental Methods.	343
6.8.3. Possible Mechanisms of Acoustically Assisted Drying	344
6.9. Ultrasonic Fatigue Testing	345
6.9.1. Introduction	345
6.9.2. Experimental Methods.	345
6.9.3. Mechanisms of Fatigue	347
6.10. Ultrasonic Processing of Materials	348
6.10.1. Introduction	348
6.10.2. Ultrasonic Welding	348
6.10.3. Ultrasonic Machining	350
6.10.4. Other Applications	352
6.11. Concluding Remarks	352
7. Acoustic Cavitation by ROBERT E. APFEL	
7.1. Introduction	356

7.1.1. Nomenclature	356
7.1.2. Types, Stages, and Effects of Acoustic Cavitation	358
7.2. Cavitation Inception	360
7.2.1. Cavitation Threshold Measurements	360
7.2.2. Cavitation and Dirt	364
7.2.3. Radiation-Induced Cavitation	366
7.2.4. Unsolved Problems	368
7.2.5. Concluding Remarks on Cavitation Thresholds . .	371
7.3. Cavitation Dynamics	372
7.3.1. General Considerations	372
7.3.2. Gas Bubbles; Noncatastrophic Dynamics	375
7.3.3. Vapor Bubble Dynamics	383
7.3.4. Transient Cavitation	385
7.3.5. Synthesis of Some of the Theoretical Results .	398
7.4. Acoustic Cavitation: Applications and Problems . . .	403
7.4.1. Introduction	403
7.4.2. Promoting Cavitation: Activity Measures for and Applications of Cavitation	404
7.4.3. Inhibiting and Avoiding the Effects of Cavitation.	406
7.5. Final Remarks	411
8. Acoustic Measurements in Superfluid Helium	
by JOSEPH HEISERMAN	
8.1. Introduction	414
8.1.1. Liquid and Superfluid Helium	414
8.1.2. The Sounds of Helium	417
8.2. Transducers	421
8.2.1. First Sound	421
8.2.2. Second Sound	429
8.2.3. Fourth Sound	434
8.3. Measurement Techniques	435
8.3.1. Resonant Methods	435
8.3.2. Pulse Methods	447
8.3.3. Calibration Techniques	450

9. Acousto-Optic Phenomena

by G. I. A. STEGEMAN

9.1. Introduction	456
9.2. Review of Light Scattering Theory	458
9.2.1. Scattering Mechanisms	458
9.2.2. Light Scattering from Bulk Waves	459
9.2.3. Light Scattering from Surface Waves	464
9.2.4. Characteristics of the Scattered Light	465
9.3. Classification of Experimental Techniques	467
9.3.1. Direct Current Detection.	468
9.3.2. Interferometric Techniques.	469
9.3.3. Heterodyne Techniques	469
9.4. Direct Current Detection.	469
9.4.1. Observation of Diffraction Orders.	470
9.4.2. Schlieren Studies	472
9.4.3. Photoelectric Detection	474
9.5. Fabry-Perot Interferometry	478
9.5.1. Basic Principles	478
9.5.2. Experimental Geometry	480
9.6. Heterodyne Techniques	481
9.6.1. General Principles.	481
9.6.2. Heterodyne Systems	482
9.6.3. Superheterodyne Techniques	487
9.7. Summary.	492

10. Surface Elastic Waves

by RICHARD M. WHITE

10.1. Introduction	496
10.2. Surface Waves in Semi-Infinite and Layered Media . .	496
10.2.1. Analysis of Waves Guided along a Surface. . .	497
10.2.2. Propagation Characteristics	499
10.2.3. Summary Comparison of Surface with Bulk Waves	508

10.3. Transduction	508
10.3.1. Interdigital Transducers	510
10.3.2. Wedge Transducers	515
10.3.3. Optical Detection	516
10.3.4. Electromagnetic Noncontacting Transducers . .	518
10.3.5. Comments on Some Experimental Problems . .	520
10.4. Surface Wave Applications	520
10.4.1. Nonmeasurement Applications	521
10.4.2. Properties of Thin Films	523
10.4.3. Sensing Fields	525
10.4.4. Semiconductor Surface Properties	526
10.4.5. Elastic Surface Properties	528
10.5. Summary and Conclusions	530
11. Acoustic Holography by B. P. HILDEBRAND	
11.1. Introduction	533
11.1.1. Phenomenological Foundation	533
11.1.2. Historical Survey	536
11.2. Fundamental Concepts	538
11.2.1. Hologram Generation	538
11.2.2. Wave Reconstruction	540
11.2.3. Image Parameters	542
11.3. Implementation	546
11.3.1. Area Detector	546
11.3.2. Sampling Detectors	549
11.4. Applications	552
11.4.1. Imaging	552
11.4.2. Interferometry	554
11.5. Computer Reconstruction	554
11.5.1. Computer Reconstruction of Holograms	555
11.5.2. Imaging by Backward Wave Reconstruction .	559

12. Computerized Transmission Tomography	
by JAMES F. GREENLEAF	
12.1. Introduction: Implementation of Tomography Methods in Medicine	563
12.1.1. Notation	565
12.1.2. List of Symbols	567
12.2. Straight Ray Transmission Tomography	568
12.2.1. Single-Frequency (Narrowband) Method	568
12.2.2. Multiple-Frequency (Broadband) Method	571
12.2.3. Reconstruction of Nonscalar Parameters Assuming Straight Rays	573
12.2.4. Reconstruction of Temperature Fields	575
12.3. Reconstruction Using Curved Rays	576
12.3.1. Ray Tracing Methods	577
12.3.2. Diffraction Tomography: An Inversion (Reconstruction) Method for Low Attenuation That Includes Curved Rays	578
12.4. Data Acquisition and Signal Analysis	580
12.4.1. Methods for Straight Line Reconstruction	581
12.4.2. Signal Analysis Methods for Pulse Arrival Time	583
12.4.3. Analysis of Amplitude of Received Signals for Reconstruction of Acoustic Attenuation	585
12.4.4. Acquisition of Data for Diffraction Tomography	587
12.4.5. Phase Interference	587
12.4.6. Measurement of Amplitude versus Frequency	588
12.4.7. Speed of Data Acquisition	588
12.5. Summary	589
AUTHOR INDEX	591
SUBJECT INDEX	606