

Contents

Chapter I

Definition, Measurement, and Generation of Structure-Borne Sound

1. Definition	1
2. Mechanical Measurement Methods and Related Considerations	3
3. Sensors that Control Electric Circuits	24
4. Electromechanical Transducers for Airborne Sound	32
a) Application to Measurement of Structure-Borne Sound	32
b) Electrodynamic Transducers	36
c) Electrostatic Transducers	45
d) Electromagnetic Transducers	54
e) Piezoelectric Transducers	58
5. Electromechanical Transducers for Structure-Borne Sound	62
a) Sensors	62
b) Exciters of Structure-Borne Sound	69

Chapter II

Survey of Wave Types and Characteristics

1. Longitudinal Waves	75
a) Pure Longitudinal Waves	75
b) Quasi-Longitudinal Waves on Beams and Plates	81
2. Transverse Waves	87
a) Transverse Plane Waves	87
b) Torsional Waves	90
3. Bending Waves	95
a) Pure Bending Waves	95
b) Corrected Bending Waves	109
4. Wave Motions on Beams of Finite Length	115
a) Longitudinal Natural Vibrations	116
b) Natural Vibrations in Bending	121
5. The General Field Equations	130

6. Wave Fields at Free Surfaces	137
a) Reflection of Plane Waves	137
α) Some Simple Special Cases	137
β) Velocity Potential and Stream Function	138
γ) Equality of Trace Velocities	140
δ) Determination of Reflection Coefficients and Reflection Efficiencies	143
b) Surface Waves	147
α) Forced Surface Waves	147
β) Free Surface Waves (Rayleigh Waves)	150
7. Free Plate Waves	152
a) Boundary Conditions and Types of Solutions	152
b) Waves with Displacements only Parallel to the Surface	155
c) Waves which also have Displacement Components Perpendicular to the Surface	158
8. Simultaneous Derivation of Plate and Shell Equations from the General Field Equations	168
a) Extensional and Shear Waves in Flat Plates	168
b) Bending waves in Flat Plates	173
c) Structure-borne Sound in Circular Cylindrical Shells	176
α) Basic Equations	176
β) Membrane Equations	181
γ) Consideration of Flexure	185
δ) Resonance Frequencies of Rings, Tubes, and Cylindrical and Spherical Shells	189

Chapter III

Damping

1. Damping Mechanisms and their Mathematical Description	195
2. The Complex Modulus of Elasticity	199
3. Resonant Vibrations of Damped Beams	204
a) Quasi-Longitudinal Waves and Torsional Waves	204
b) Bending Waves	211
4. Measurement of Complex Moduli	215
a) Measurements on Small Samples	216
α) Stress-Strain Curve	216
β) Mechanical Impedance	218
γ) Vibration Decay	221
δ) Resonance Frequency and Half-Value Bandwidth	223
b) Measurements on Beams	224
α) Half-Value Bandwidth	225
β) Decay Time	227
γ) Attenuation of Vibrations with Distance	228
δ) Other Methods	230
c) Measurements on Other than Beam-Like Samples	230
5. Experimental Data	231
a) Metals	231

b)	Plastics	238
c)	Building Materials	241
6.	Plates with Attached Layers	243
a)	Plates with Simple, Extensionally Loaded Layers	243
b)	Plates with Multi-Layer Treatments	247
α)	Stiff Base Plate with Thin Cover Plate	249
β)	Two Equal Plates with Thin Interlayer	252
γ)	General Composite Plate or Beam Configurations	255
c)	Damping by Means of Resonant Systems	255
7.	Other Damping Mechanisms	261
a)	Damping at Metal Interfaces; Air Pumping	261
b)	Damping by Granular Materials	263

Chapter IV

Impedances

1.	Definition of Point-Impedance	266
2.	Measurement of Mechanical Impedances	268
a)	Measurement of Force and Velocity	268
b)	Comparison with Known Impedance	271
3.	Input Impedances of Infinite Beams and Plates	275
a)	Quasi-Longitudinal Waves in Beams	275
b)	Bending Waves in Beams	278
c)	Bending-Wave Equation for Homogeneous Thin Plates	283
d)	Driving-Point Impedance of Homogeneous Plates in Flexure	286
e)	Analysis of Plate Flexural Vibrations by Means of Fourier Trans- forms	295
f)	Driving-Point Impedance of Thick Plates in Flexure	298
g)	Driving Point Impedance of Orthotropic Plates in Bending	301
h)	Impedances of Plate Strips and Tubes	304
i)	Moment Impedances	311
j)	Summary of Impedance Formulas	315
4.	Point-Excitation of Finite Systems	318
a)	General Properties	318
b)	Some Applications	323
c)	Power Considerations	327
5.	Some Specific Applications	333
a)	Footfall Noise	333
b)	Isolation of Machinery	339

Chapter V

Attenuation of Structure-Borne Sound

1.	Changes in Material and Cross-Section	342
a)	Attenuation of Longitudinal Waves	343
b)	Attenuation of Bending Waves	347
2.	Corners and Branches at Right Angles	352

3. Elastic Interlayers	370
a) Attenuation of Longitudinal Waves	370
b) Attenuation of Bending Waves	375
4. Blocking Masses	385
a) Attenuation of Longitudinal Waves	386
b) Attenuation of Bending Waves	388
c) Coupling of Longitudinal and Bending Waves	402
5. Spatially Periodic Structures	405
a) Transmission and Attenuation of Longitudinal Waves	405
b) Cascades of Flexural Elements	415
6. Oblique Incidence	425
a) General Considerations	425
b) General Consequences of the Boundary Conditions	431
c) Two-Dimensional Analysis of Walls Joined at Right Angles	436
d) Plate with Reinforcing Beam	437
7. Parallel Plates	450
a) Continuous Coupling by Elastic Interlayer (Floating Floor)	450
b) Point-Acting Sound Bridges	462
8. Statistical Energy Analysis	474
a) Introduction	474
b) Power Flow between Linearly Coupled Oscillators	478
c) Coupled Multimodal Systems	482
d) Applications	485

Chapter VI

Sound Radiation from Structures

1. Measurement of Radiated Power	492
2. Definition and Measurement of Radiation Efficiency	495
3. Radiation Loss Factor	497
4. Elementary Radiators	499
a) Spherical Radiators	499
b) Infinite Plates	502
c) Cylindrical Radiators	505
5. Plane Radiator as Array of Point Sources	510
a) Rectangular Array of Point Sources	512
b) Membrane with Axially Symmetric Velocity Distribution	519
6. Radiation from Bending Waves	523
a) Critical Frequency	523
b) Bending Waves on Finite Plates	526
c) Radiation from Flexural Nearfield at Excitation Point	534
d) Some Experimental Results	537
e) Radiation from Point-Excited Tubes	540
7. Plate Response to Excitation by Airborne Sound (Attenuation of Airborne Sound)	543

a)	Response of Homogeneous Plates	544
b)	Double-Walls with Sound Bridges	548
8.	Relation between Radiation and Response	550
a)	Reciprocity	550
b)	Response and Radiation in a Reverberant Room	551
c)	Effect of Radiation Loading	554
d)	Attenuation and Flanking Transmission Above the Critical Frequency	556
e)	Relation between Airborne and Impact Sound Transmission	560
f)	Application of Statistical Energy Analysis	563
Index	565