

# Contents

<b>1</b>	<b>Introduction</b>	1
1.1	Definition of Three Basic Terms	1
1.2	Specialized Areas within Acoustics	3
1.3	About the History of Acoustics	4
1.4	Relevant Quantities in Acoustics	5
1.5	Some Numerical Examples	6
1.6	Levels and Logarithmic Frequency Intervals	8
1.7	Double-Logarithmic Plots	10
<b>2</b>	<b>Mechanic and Acoustic Oscillations</b>	13
2.1	Basic Elements of Linear, Oscillating, Mechanic Systems	14
2.2	Parallel Mechanic Oscillators	16
2.3	Free Oscillations of Parallel Mechanic Oscillators	17
2.4	Forced Oscillation of Parallel Mechanic Oscillators	19
2.5	Energies and Dissipation Losses	22
2.6	Basic Elements of Linear, Oscillating, Acoustic Systems	24
2.7	The <i>Helmholtz</i> Resonator	25
<b>3</b>	<b>Electromechanic and Electroacoustic Analogies</b>	27
3.1	The Electromechanic Analogies	28
3.2	The Electroacoustic Analogy	29
3.3	Levers and Transformers	29
3.4	Rules for Deriving Analogous Electric Circuits	31
3.5	Synopsis of Electric Analogies of Simple Oscillators	33
3.6	Circuit Fidelity, Impedance Fidelity and Duality	33
3.7	Examples of Mechanic and Acoustic Oscillators	34
<b>4</b>	<b>Electromechanic and Electroacoustic Transduction</b>	37
4.1	Electromechanic Couplers as Two- or Three-Port Elements	38
4.2	The Carbon Microphone – A Controlled Coupler	39
4.3	Fundamental Equations of Electroacoustic Transducers	40

## VIII    Contents

4.4	Reversibility .....	43
4.5	Coupling of Electroacoustic Transducers to the Sound Field .....	44
4.6	Pressure and Pressure-Gradient Receivers .....	46
4.7	Further Directional Characteristics .....	49
4.8	Absolute Calibration of Transducers .....	52
<b>5</b>	<b>Magnetic-Field Transducers .....</b>	<b>55</b>
5.1	The Magnetodynamic Transduction Principle .....	57
5.2	Magnetodynamic Sound Emitters and Receivers .....	59
5.3	The Electromagnetic Transduction Principle .....	65
5.4	Electromagnetic Sound Emitters and Receivers .....	67
5.5	The Magnetostrictive Transduction Principle .....	68
5.6	Magnetostrictive Sound Transmitters and Receivers .....	69
<b>6</b>	<b>Electric-Field Transducers .....</b>	<b>71</b>
6.1	The Piezoelectric Transduction Principle .....	71
6.2	Piezoelectric Sound Emitters and Receivers .....	74
6.3	The Electrostrictive Transduction Principle .....	78
6.4	Electrostrictive Sound Emitters and Receivers .....	79
6.5	The Dielectric Transduction Principle .....	80
6.6	Dielectric Sound Emitters and Receivers .....	81
6.7	Further Transducer and Coupler Principles .....	85
<b>7</b>	<b>The Wave Equation in Fluids .....</b>	<b>87</b>
7.1	Derivation of the One-Dimensional Wave Equation .....	89
7.2	Three-Dimensional Wave Equation in <i>Cartesian</i> Coordinates ..	94
7.3	Solutions of the Wave Equation .....	95
7.4	Field Impedance and Power Transport in Plane Waves .....	96
7.5	Transmission-Line Equations and Reflectance .....	97
7.6	The Acoustic Measuring Tube .....	99
<b>8</b>	<b>Horns and Stepped Ducts .....</b>	<b>103</b>
8.1	<i>Webster's</i> Differential Equation – the Horn Equation .....	104
8.2	Conical Horns .....	105
8.3	Exponential Horns .....	107
8.4	Radiation Impedances and Sound Radiation .....	110
8.5	Steps in the Area Function .....	111
8.6	Stepped Ducts .....	113
<b>9</b>	<b>Spherical Sound Sources and Line Arrays .....</b>	<b>117</b>
9.1	Spherical Sound Sources of 0 <sup>th</sup> Order .....	118
9.2	Spherical Sound Sources of 1 <sup>st</sup> Order .....	122
9.3	Higher-Order Spherical Sound Sources .....	124
9.4	Line Arrays of Monopoles .....	125
9.5	Analogy to <i>Fourier</i> Transforms as Used in Signal Theory .....	127
9.6	Directional Equivalence of Sound Emitters and Receivers .....	130

<b>10</b>	<b>Piston Membranes, Diffraction and Scattering</b>	133
10.1	The <i>Rayleigh</i> Integral	134
10.2	<i>Fraunhofer's</i> Approximation	135
10.3	The Far Field of Piston Membranes	136
10.4	The Near Field of Piston Membranes	138
10.5	General Remarks on Diffraction and Scattering	142
<b>11</b>	<b>Dissipation, Reflection, Refraction, and Absorption</b>	145
11.1	Dissipation During Sound Propagation in Air	147
11.2	Sound Propagation in Porous Media	148
11.3	Reflection and Refraction	151
11.4	Wall Impedance and Degree of Absorption	152
11.5	Porous Absorbers	155
11.6	Resonance Absorbers	158
<b>12</b>	<b>Geometric Acoustics and Diffuse Sound Fields</b>	161
12.1	Mirror Sound Sources and Ray Tracing	162
12.2	Flutter Echoes	165
12.3	Impulse Responses of Rectangular Rooms	167
12.4	Diffuse Sound Fields	169
12.5	Reverberation-Time Formulae	172
12.6	Application of Diffuse Sound Fields	173
<b>13</b>	<b>Isolation of Air- and Structure-Borne Sound</b>	177
13.1	Sound in Solids – Structure-Borne Sound	177
13.2	Radiation of Airborne Sound by Bending Waves	179
13.3	Sound-Transmission Loss of Single-Leaf Walls	181
13.4	Sound-Transmission Loss of Double-Leaf Walls	184
13.5	The Weighted Sound-Reduction Index	186
13.6	Isolation of Vibrations	189
13.7	Isolation of Floors with Regard to Impact Sounds	192
<b>14</b>	<b>Noise Control – A Survey</b>	195
14.1	Origins of Noise	196
14.2	Radiation of Noise	196
14.3	Noise Reduction as a System Problem	200
14.4	Noise Reduction at the Source	203
14.5	Noise Reduction Along the Propagation Paths	204
14.6	Noise Reduction at the Receiver's End	208
<b>15</b>	<b>Appendices</b>	211
15.1	Complex Notation for Sinusoidal Signals	211
15.2	Complex Notation for Power and Intensity	212
15.3	Supplementary Textbooks for Self Study	214
15.4	Exercises	215
15.5	Letter Symbols, Notations and Units	234
<b>Index</b>		239