

CONTENTS

PREFACE TO THE SECOND EDITION vii

PREFACE TO THE FIRST EDITION ix

CHAPTER I

INTRODUCTORY

SECTION

1. <i>Definitions and Methods</i>	1
Units. Energy	
2. <i>A Little Mathematics</i>	3
The Trigonometric Functions. Bessel Functions. The Exponential. Conventions as to Sign. Other Solutions. Contour Integrals. Infinite Integrals. Fourier Transforms	
<i>Problems</i>	17

CHAPTER II

THE SIMPLE OSCILLATOR

3. <i>Free Oscillations</i>	20
The General Solution. Initial Conditions. Energy of Vibration	
4. <i>Damped Oscillations</i>	23
The General Solution. Energy Relations	
5. <i>Forced Oscillations</i>	27
The General Solution. Transient and Steady State. Impedance and Phase Angle. Energy Relations. Electro-mechanical Driving Force. Motional Impedance. Piezo-electric Crystals	

SECTION

6. <i>Response to Transient Forces</i>	42
Representation by Contour Integrals. Transients in a Simple System. Complex Frequencies. Calculating the Transients. Examples of the Method. The Unit Function. General Transient. Some Generalizations. Laplace Transforms	
7. <i>Coupled Oscillations</i>	52
The General Equation. Simple Harmonic Motion. Normal Modes of Vibration. Energy Relations. The Case of Small Coupling. The Case of Resonance. Transfer of Energy. Forced Vibrations. Resonance and Normal Modes. Transient Response	
<i>Problems</i>	66

CHAPTER III

THE FLEXIBLE STRING

8. <i>Waves on a String</i>	71
The Wave Velocity. The General Solution for Wave Motion. Initial Conditions. Boundary Conditions. Reflection at a Boundary. Strings of Finite Length	
9. <i>Simple Harmonic Oscillations</i>	80
The Wave Equation. Standing Waves. Normal Modes. Fourier Series. Initial Conditions. The Series Coefficients. Plucked String, Struck String. Energy of Vibration	
10. <i>Forced Vibrations</i>	91
Wave Impedance and Admittance. General Driving Force. String of Finite Length. Driving Force Applied Anywhere. Alternative Series Form. Distributed Driving Force. Transient Driving Force. The Piano String. The Effect of Friction. Characteristic Impedances and Admittances	
11. <i>Strings of Variable Density and Tension</i>	107
General Equation of Motion. Orthogonality of Characteristic Functions. Driven Motion. Nonuniform Mass. The Sequence of Characteristic Functions. The Allowed	

SECTION

	Frequencies. Vibrations of a Whirling String. The Allowed Frequencies. The Shape of the String. Driven Motion of the Whirling String	
12.	<i>Perturbation Calculations.</i>	122
	The Equation of Motion. First-order Corrections. Examples of the Method. Characteristic Impedances. Forced Oscillation. Transient Motion	
13.	<i>Effect of Motion of the End Supports.</i>	133
	Impedance of the Support. Reflection of Waves. Hyperbolic Functions. String Driven from One End. Shape of the String. Standing Wave and Position of Minima. Characteristic Functions. Transient Response. Recapitulation	
	<i>Problems</i>	147

CHAPTER IV

THE VIBRATION OF BARS

14.	<i>The Equation of Motion.</i>	151
	Stresses in a Bar. Bending Moments and Shearing Forces. Properties of the Motion of the Bar. Wave Motion in an Infinite Bar	
15.	<i>Simple Harmonic Motion</i>	156
	Bar Clamped at One End. The Allowed Frequencies. The Characteristic Functions. Plucked and Struck Bar. Clamped-clamped and Free-free Bars. Energy of Vibration. Nonuniform Bar. Forced Motion	
16.	<i>Vibrations of a Stiff String.</i>	166
	Wave Motion on a Wire. The Boundary Conditions. The Allowed Frequencies	
	<i>Problems</i>	170

CHAPTER V

MEMBRANES AND PLATES

17.	<i>The Equation of Motion.</i>	172
	Forces on a Membrane. The Laplacian Operator. Bound-	

SECTION

	ary Conditions and Coordinate Systems. Reaction to a Concentrated Applied Force	
18.	<i>The Rectangular Membrane</i>	177
	Combinations of Parallel Waves. Separating the Wave Equation. The Normal Modes. The Allowed Frequencies. The Degenerate Case. The Characteristic Functions	
19.	<i>The Circular Membrane</i>	183
	Wave Motion on an Infinite Membrane. Impermanence of the Waves. Simple Harmonic Waves. Bessel Functions. The Allowed Frequencies. The Characteristic Functions. Relation between Parallel and Circular Waves. The Kettledrum. The Allowed Frequencies	
20.	<i>Forced Motion. The Condenser Microphone</i>	195
	Neumann Functions. Unloaded Membrane, Any Force. Localized Loading, Any Force. Uniform Loading, Uniform Force. The Condenser Microphone. Electrical Connections. Transient Response of Microphone	
21.	<i>The Vibration of Plates</i>	208
	The Equation of Motion. Simple Harmonic Vibrations. The Normal Modes. Forced Motion	
	<i>Problems</i>	213

CHAPTER VI

PLANE WAVES OF SOUND

22.	<i>The Equation of Motion</i>	217
	Waves along a Tube. The Equation of Continuity. Compressibility of the Gas. The Wave Equation. Energy in a Plane Wave. Intensity. The Decibel Scale. Intensity and Pressure Level. Sound Power. Frequency Distribution of Sounds. The Vowel Sounds	
23.	<i>The Propagation of Sounds in Tubes</i>	233
	Analogous Circuit Elements. Constriction. Tank. Examples. Characteristic Acoustic Resistance. Incident and Reflected Waves. Specific Acoustic Impedance.	

SECTION

Standing Waves. Measurement of Acoustic Impedance. Damped Waves. Closed Tube. Open Tube. Small- diameter Open Tube. Reed Instruments. Motion of the Reed. Pressure and Velocity at the Reed. Even Har- monics. Other Wind Instruments. Tube as an Analo- gous Transmission Line. Open Tube, Any Diameter. Cavity Resonance. Transient Effects, Flutter Echo	
24. <i>Propagation of Sound in Horns</i>	265
One-parameter Waves. An Approximate Wave Equation. Possible Horn Shapes. The Conical Horn. Transmission Coefficient. A Horn Loud-speaker. The Exponential Horn. The Catenoidal Horn. Reflection from the Open End, Resonance. Wood-wind Instruments. Transient Effects	
<i>Problems</i>	288

CHAPTER VII

THE RADIATION AND SCATTERING OF SOUND

25. <i>The Wave Equation</i>	294
The Equation for the Pressure Wave. Curvilinear Coordi- nates	
26. <i>Radiation from Cylinders</i>	297
The General Solution. Uniform Radiation. Radiation from a Vibrating Wire. Radiation from an Element of a Cylinder. Long- and Short-wave Limits. Radiation from a Cylindrical Source of General Type. Transmission inside Cylinders. Wave Velocities and Characteristic Imped- ances. Generation of Wave by Piston	
27. <i>Radiation from Spheres</i>	311
Uniform Radiation. The Simple Source. Spherical Waves of General Form. Legendre Functions. Bessel Functions for Spherical Coordinates. The Dipole Source. Radiation from a General Spherical Source. Radiation from a Point Source on a Sphere. Radiation from a Piston Set in a Sphere	

SECTION

28. <i>Radiation from a Piston in a Plane Wall</i>	326
Calculation of the Pressure Wave. Distribution of Intensity. Effect of Piston Flexure on Directionality. Radiation Impedance, Rigid Piston. Distribution of Pressure over the Piston. Nonuniform Motion of the Piston. Radiation out of a Circular Tube. Transmission Coefficient for a Dynamic Speaker. Design Problems for Dynamic Speakers. Behavior of the Loud-speaker. Transient Radiation from a Piston	
29. <i>The Scattering of Sound</i>	346
Scattering from a Cylinder. Short Wavelength Limit. Total Scattered Power. The Force on the Cylinder. Scattering from a Sphere. The Force on the Sphere. Design of a Condenser Microphone. Behavior of the Microphone	
30. <i>The Absorption of Sound at a Surface</i>	360
Surface Impedance. Unsupported Panel. Supported Panel. Porous Material. Equivalent Circuits for Thin Structures. Formulas for Thick Panels. Reflection of Plane Wave from Absorbing Wall	
31. <i>Sound Transmission through Ducts</i>	368
Boundary Conditions. Approximate Solutions. Principal Wave. Transient Waves. The Exact Solution. An Example	
<i>Problems</i>	376

CHAPTER VIII

STANDING WAVES OF SOUND

32. <i>Normal Modes of Vibration</i>	381
Room Resonance. Statistical Analysis for High Frequencies. Limiting Case of Uniform Distribution. Absorption Coefficient. Reverberation. Reverberation Time. Absorption Coefficient and Acoustic Impedance. Standing Waves in a Rectangular Room. Distribution in Frequency of the Normal Modes. Axial, Tangential, and Oblique Waves. Average Formulas for Numbers of Allowed Frequencies. Average Number of Frequencies in Band	

SECTION

The Effect of Room Symmetry. Nonrectangular Rooms. Frequency Distribution for Cylindrical Room

33. *Damped Vibrations, Reverberation*. 401

 Rectangular Room, Approximate Solution. Wall Coefficients and Wall Absorption. Reverberation Times for Oblique, Tangential, and Axial Waves. Decay Curve for Rectangular Room. Cylindrical Room. Second-order Approximation. Scattering Effect of Absorbing Patches

34. *Forced Vibrations*. 413

 Simple Analysis for High Frequencies. Intensity and Mean-square Pressure. Solution in Series of Characteristic Functions. Steady-state Response of a Room. Rectangular Room. Transmission Response. The Limiting Case of High Frequencies. Approximate Formula for Response. Exact Solution. The Wall Coefficients. Transient Calculations, Impulse Excitation. Exact Solution for Reverberation

Problems 429

BIBLIOGRAPHY. 433

GLOSSARY OF SYMBOLS 435

TABLES OF FUNCTIONS 438

 I and II, Trigonometric and Hyperbolic Functions. III and IV, Hyperbolic Tangent of Complex Quantity. V, VI and VII, Bessel Functions. VIII, Impedance Functions for Piston. IX, Legendre Functions. XII, General Impedance Functions for Piston. XIII, Absorption Coefficients

PLATES. 453

 I and II, Hyperbolic Tangent Transformation. III, Magnitude and Phase Angles of sinh and cosh. IV, Standing Wave Ratio and Phase *vs.* Acoustic Impedance. V, Exact Solutions for Wave Modes in Rectangular Ducts and Rooms. VI, Absorption Coefficient *vs.* Acoustic Impedance

INDEX 459