

# CONTENTS

	Page
FOREWORD.....	XI
PREFACE .....	XIII
CHAPTER 1. THE PHYSICAL NATURE OF WIND WAVES.....	1
The Growth and Decay of Waves.....	6
The Depth of Wave Action.....	9
Hurricane or "Tidal" Waves.....	12
CHAPTER 2. THE DIMENSIONS OF WAVES.....	15
The Heights of Waves.....	15
The Average Heights of Waves.....	21
The Maximum Heights of Storm Waves.....	23
Single High Waves and Groups of High Waves.....	25
The Lengths of Waves.....	26
The Steepness of Waves.....	28
The Velocities and Periods of Waves.....	31
The Directions in Which Wind Waves Advance.....	37
CHAPTER 3. THE CONTOURS OF WAVES; THE EFFECTS OF CURRENTS AND OF SHOAL WATER; THE MEASUREMENT OF WAVES.....	43
The Profiles and Surface Contours of Waves.....	43
The Effects of Currents on the Dimensions of Waves.....	51
Alterations in the Dimensions of Waves Over a Shoaling Bottom.....	56
The Sizes of Waves That Are Developed in Shallow Water.....	58
Methods of Measuring Waves.....	60
CHAPTER 4. SEAS AND SWELLS.....	63
Alteration of Seas Into Swells.....	63
The Directions of Swells.....	67
The Persistence of Swells.....	69
Forecasting Sea and Swell.....	70
CHAPTER 5. THE FREQUENCY OF HIGH AND LOW SEAS AND SWELLS IN DIFFERENT REGIONS.....	71
North Atlantic.....	72
Summer.....	72
Winter.....	77
South Atlantic.....	80
North Pacific.....	82
Summer.....	82
Winter.....	86
South Pacific.....	90
North Indian Ocean.....	93
Summer.....	93
Winter.....	95
South Indian Ocean.....	96
CHAPTER 6. BREAKERS AND SURF; THEIR IMPORTANCE AND ORIGIN...	99
The Importance of Surf.....	99
The Causes of Surf.....	102
Alterations in Length and in Velocity Over a Shoaling Bottom.....	103
Alterations in Height Over a Shoaling Bottom.....	106
Alterations in Steepness.....	109
Alterations in the Orbital Velocities of the Water Particles.....	109

	Page
<b>CHAPTER 6. BREAKERS AND SURF—Continued</b>	
The Characteristics of Breakers.....	110
Waves of Translation.....	115
<b>CHAPTER 7. THE CHARACTER OF SURF UNDER DIFFERENT CONDITIONS..</b>	119
The Height of Surf.....	119
Depth of Water in which Surf Develops.....	126
The Stage of the Tide as It Affects the Surf.....	132
Distance of the First Line of Breakers out from the Shore; Effects of Bars; Number of Lines of Breakers.....	133
Factors that Hinder the Development of Surf or that Tend to Interrupt It.....	145
Ledges, Shoals, and Islands.....	145
Tidal Currents.....	145
Rip Currents.....	146
Hail and Ice.....	147
Marsh Grasses and Seaweeds.....	147
Oil.....	149
The Persistence of Surf and Its Relationship to the Wind.....	150
<b>CHAPTER 8. DIRECTION AND HEIGHT OF BREAKERS IN RELATION TO THE   SHAPE OF THE COAST.....</b>	155
The Refraction of Waves.....	155
The Loss of Wave Height by Refraction.....	157
Surf around the Shores of Bays.....	159
Surf around Headlands.....	163
Surf around Islands.....	168
Submarine Troughs and Ridges as Affecting Surf.....	175
Forecasting Breakers and Surf.....	176
Selected References.....	177

## TABLES

TABLE	Page
1. Mass transport in waves of different dimensions.....	6
2. Relative diameters of orbital motion with increasing depth.....	10
3. Maximum heights of waves with winds of different strengths.....	17
4. Heights of waves with winds of different strengths and durations.....	18
5. Heights of waves with winds of different strengths blowing over different fetches.....	18
6. Minimum, maximum, and average wave heights for the Trade Wind Belts.....	18
7. Fetches and durations required to produce waves 75 percent of maximum height with different winds.....	20
8. Frequency of waves of different heights in different regions.....	21
9. Frequency of waves of different heights at South Beach, Martha's Vineyard.....	22
10. Average lengths of waves according to the strength of the wind.....	27
11. Lengths of storm waves observed in different oceans.....	28
12. Average steepness of waves for winds of different strengths and durations.....	29
13. Maximum, minimum, and mean steepness of waves of different heights.....	30
14. Correlation between age and steepness of growing waves.....	31
15. Theoretical wave periods and velocities in relation to the strength and duration of the wind.....	32
16. Theoretical velocities and lengths for waves of different periods.....	35
17. Lengths and periods of waves computed from observed periods and lengths in different parts of the oceans.....	36
18. Ratios between the dimensions of waves in still water and in currents.....	53
19. Distribution of low, medium, and high seas in different latitudinal belts of the North Atlantic in August.....	73
20. Frequencies of high swells on the American and European sides of the North Atlantic in January and February.....	80
21. Frequencies of low and high seas and swells on the American and African sides of the South Atlantic in July and August.....	82
22. Frequencies of low and high seas and swells on the American and African sides of the South Atlantic in January and February.....	82
23. Frequency of no swell in the Japan and South China seas in summer and winter.....	90
24. Frequencies of high seas and swells off the west coast of South America.....	91
25. Frequencies of low and high seas and swells in the Arabian Sea and Bay of Bengal in winter and summer.....	95
26. Frequencies of low and high seas and swells along the Equatorial Belt and Southeast Trades Belt of the South Indian Ocean in winter and summer.....	98
27. Pressures of breakers on the west coast of Scotland.....	101
28. Pressures of waves at St. Augustine, Florida and Duluth Canal, Lake Superior.....	101
29. Decrease in wave lengths and velocities over a shoaling bottom.....	104
30. Frequencies of waves of different periods at South Beach, Martha's Vineyard.....	106

TABLE	Page
31. Alterations in wave height over a shoaling bottom.....	108
32. Breaker heights, and depths at which breaking occurs for waves of different dimensions.....	121
33. Ratio of breaker height to offshore height for waves of different degrees of steepness.....	121
34. Frequencies of breakers higher than 5 and 10 feet along the east coast of the United States.....	151
35. Angles of breakers with the beach for waves of different degrees of steepness approaching at different angles.....	157
36. Alteration of the angle between wave crest and shore line in shoaling water.....	157
37. Decrease in wave height due to refraction over a shoaling bottom....	159

# ILLUSTRATIONS

## Figures in Text

FIGURE	Page
U. S. Navy destroyer in a heavy sea.....	Frontispiece
1. Movements of beach grass in a low swell.....	3
2. Orbital movements of water particles in wind waves.....	4
3. Movements of water particles in shallow water.....	4
4. Ripple marks at the bottom of the Gulf of Maine.....	12
5. Graph showing the theoretical relationship between wave lengths, velocities, and periods in deep water.....	36
6. Isobaric distribution over the North Atlantic.....	39
7. Diagram showing the relative directions of the advance of waves and of winds by which they are generated.....	40
8. Directions of winds and waves in a tropical hurricane.....	40
9. Profile of a wave of trochoid form.....	43
10. Profile of a trochoid wave showing angle of a boat at steepest part of crest.....	44
11. Theoretical profile of steepest possible wave.....	44
12. Profiles of waves of different degrees of steepness.....	45
13. Smaller waves running on top of an older swell.....	47
14. Moderately heavy sea in the North Atlantic.....	48
15. Surface configuration of the front of a wave about 19 feet high.....	49
16. Surface configuration of the back of a wave 27 feet high.....	50
17. Peaks developed by interference.....	52
18. A moderately high and breaking sea.....	64
19. Back of the crest of a high and breaking storm wave.....	65
20. Diagram to show changes in directions from which swells come with the advance of a storm center.....	68
21. Graph showing the theoretical alteration of waves advancing over a shoaling bottom.....	103
22. A breaker of the plunging type, showing stages of development.....	111
23. Oblique view of a breaker of the plunging type.....	112
24. Aerial photograph of breakers of the plunging type.....	113
25. Breakers of spilling and plunging types.....	114
26. A breaker intermediate between plunging and spilling types.....	116
27. A wave of translation preceding a breaker up a gently sloping beach.....	117
28. Heavy surf beating against the boulevard at Winthrop, Mass.....	119
29. Surf almost wholly enveloping Minot's Light, Massachusetts.....	120
30. Breakers caused by swells which are hardly visible offshore.....	125
31. Pattern produced by breakers from different directions.....	128
32. Waves breaking farther out at the mouth of a tidal inlet than along the neighboring beach.....	129
33. Breaker developing against the base of Minot's Light, Massachusetts.....	133
34. Wave breaking close to the tide line on a steeply sloping beach.....	134
35. Surf extending 5,000 feet out from shore.....	136
36. Surf developing over bars, with and without surf on the beach.....	137
37. Surf with two chief lines of breakers off the Hawaiian Islands.....	138
38. Moderately heavy breakers on two bars and on the beach behind them.....	139

## VIII

## ILLUSTRATIONS

FIGURE	Page
39. Five or six lines of breakers with breaking waves farther offshore.....	141
40. Low breakers over neighboring shoals, and same locality at low tide..	143
41. Heavy breakers off Adak, Aleutians.....	144
42. Aerial photograph of a rip current.....	146
43. Smooth sea in an ice field.....	148
44. Breaker developing against an offshore wind.....	152
45. Refraction of waves around headland and islet into a bay.....	156
46. Diagram illustrating the refraction of waves along a straight shore line.....	158
47. Diagram of waves advancing from two directions onto a short, rounded beach.....	161
48. Chart of St. Mary Bay, Nova Scotia.....	163
49. Surf around a low-lying projection of the Hawaiian coast.....	164
50. Surf dashing against headland at the entrance to Havana Harbor....	164
51. Diagram illustrating the refraction of waves around an abrupt corner of the coast.....	166
52. Sketch map of Duluth Harbor.....	168
53. Diagram illustrating the refraction of waves around a circular island..	169
54. Chart of No Man's Land, Massachusetts.....	171
55. Chart of St. Pierre Island, off the south coast of Newfoundland.....	172
56. Chart of Nukuoro Atoll, Caroline Group.....	174
57. Chart of Arno Atoll, Marshall Group.....	175

## PLATE LEGENDS

Plates follow Chapter 5

- Plate I.—Distribution of high seas in the North Atlantic in August and in the South Atlantic in July and August.
- Plate II.—Distribution of low seas in the North Atlantic in August and in the South Atlantic in July and August.
- Plate III.—Distribution of high swells in the North Atlantic in August and in the South Atlantic in July and August.
- Plate IV.—Distribution of low swells in the North Atlantic in August and in the South Atlantic in July and August.
- Plate V.—Distribution of high seas in the North and South Atlantic in January and February.
- Plate VI.—Distribution of low seas in the North and South Atlantic in January and February.
- Plate VII.—Distribution of high swells in the North and South Atlantic in January and February.
- Plate VIII.—Distribution of low swells in the North and South Atlantic in January and February.
- Plate IX.—Distribution of high seas in the North Pacific in August and in the South Pacific in July and August.
- Plate X.—Distribution of low seas in the North Pacific in August and in the South Pacific in July and August.
- Plate XI.—Distribution of high swells in the North Pacific in August and in the South Pacific in July and August.
- Plate XII.—Distribution of low swells in the North Pacific in August and in the South Pacific in July and August.
- Plate XIII.—Distribution of high seas in the North Pacific in February and in the South Pacific in January and February.
- Plate XIV.—Distribution of low seas in the North Pacific in February and in the South Pacific in January and February.
- Plate XV.—Distribution of high swells in the North Pacific in February and in the South Pacific in January and February.
- Plate XVI.—Distribution of low swells in the North Pacific in February and in the South Pacific in January and February.
- Plate XVII.—Distribution of high seas in the Indian Ocean in July and August.
- Plate XVIII.—Distribution of low seas in the Indian Ocean in July and August.
- Plate XIX.—Distribution of high swells in the Indian Ocean in July and August.
- Plate XX.—Distribution of low swells in the Indian Ocean in July and August.
- Plate XXI.—Distribution of high seas in the Indian Ocean in January and February.
- Plate XXII.—Distribution of low seas in the Indian Ocean in January and February.
- Plate XXIII.—Distribution of high swells in the Indian Ocean in January and February.
- Plate XXIV.—Distribution of low swells in the Indian Ocean in January and February.