

Contents

	<i>Preface to the Second Edition</i>	page xi
	<i>Preface to the First Edition</i>	xiii
1	Background	1
	1.1 Equations for fluid motion	3
	1.2 Boundary conditions	8
	1.3 Conservation relations	10
	1.4 Terminology	13
2	Non-linear single-layer flow: classical hydraulics	16
	2.1 Basic equations	16
	2.2 Flows with small obstacle height	17
	2.3 One-dimensional non-linear hydrostatic flow	31
	2.4 Downslope flows with frictional drag	48
	2.5 Granular flows	54
3	Non-linear single-layer flow past obstacles: jumps, bores and wave dispersion	56
	3.1 Non-linear waves	56
	3.2 The QRS framework	61
	3.3 Application to hydraulic jumps and undular bores	66
	3.4 Single-layer flow over topography with non-linearity and dispersion	71
	3.5 Non-linear flow past three-dimensional obstacles	78
4	Two-layer flow with jumps and topography	95
	4.1 Basic equations	95
	4.2 Linear waves	97
	4.3 Equations for one-dimensional non-linear hydrostatic flow	98
	4.4 Two-layer hydraulic jumps	102
	4.5 Hydrostatic flow over topography	109

viii	<i>Contents</i>	
	4.6 Non-linear waves and internal bores	120
	4.7 Topographic forcing with non-linearity and dispersion	124
	4.8 Downstream effects	126
5	Two-layer and stratified flow through contractions	129
	5.1 Two-layered flow through contractions with a free upper surface	130
	5.2 Two-layered flow through contractions with a rigid upper boundary	132
	5.3 Non-linearity with dispersion in contractions	141
	5.4 Multi-layered flow through contractions	142
	5.5 Continuously stratified flow through contractions	145
6	Exchange flows	148
	6.1 Two-layer exchange flow in a uniform channel over topography	149
	6.2 Two-layer exchange flow through contractions	149
	6.3 Exchange flows through doorways and windows	163
	6.4 Multi-layer and continuously stratified exchange flows	164
7	Gravity currents, downslope and anabatic flows, and stratified hydraulic jumps	172
	7.1 Gravity currents over horizontal terrain in uniform environments	172
	7.2 Gravity currents in density-stratified environments	176
	7.3 Gravity currents down slopes	179
	7.4 Hydraulic jumps in stratified flow	189
	7.5 Anabatic flows	192
8	Waves in stratified fluids	196
	8.1 Waves in multi-layered models	196
	8.2 Continuously stratified fluids: equations	202
	8.3 Waves in finite-depth systems	205
	8.4 Waves in infinitely deep stratified fluids	211
	8.5 Trapped and leaky modes	217
	8.6 The effects of molecular viscosity and diffusion on internal waves	220
	8.7 Energy and momentum transport in a non-uniformly moving fluid	221
	8.8 The “slowly varying” or WKB approximation	226
	8.9 Critical layers	229
	8.10 Wave-overturning and saturation	238
	8.11 Wave propagation in three dimensions	239
9	The stability of stratified flows	243
	9.1 Stability of stratified shear flow: a general criterion	244

<i>Contents</i>		ix
9.2	The process and products of the instability of shear flows	245
9.3	Instability in laminar boundary-layers: Tollmien–Schlichting waves	254
9.4	The stability of internal waves	259
10	Stratified flow over two-dimensional obstacles: linear and near-linear theory	261
10.1	Observations of flows of infinite depth	263
10.2	Infinite-depth flows: theory for small Nh/U	275
10.3	Infinite-depth flows: finite-amplitude topography and “Long’s model”	286
10.4	Infinite-depth flows with $Nh/U > (Nh/U)_c$: numerical studies	294
10.5	Linear theory for small Nh_m/U : finite depth	297
10.6	Comparison between linear theory, and observations and numerical results for finite depth and small Nh/U	304
10.7	Long-model solutions for finite depth	313
11	Stratified flow over two-dimensional obstacles: non-linear hydraulic models with applications	321
11.1	Models with non-linearity and dispersion	321
11.2	Non-linear hydraulic flow theory for finite depth	325
11.3	Applications of the hydraulic theory	336
11.4	The approach to continuous stratification	344
11.5	Observations and numerical results for finite Nh/U in finite depth: short obstacles	358
11.6	Application of the hydraulic model to infinite-depth flows	365
11.7	Flows with large Nh/U : deep blocked flow, topographic drag and clear-air turbulence	368
11.8	Details of the dynamics of downslope windstorms	372
11.9	Flow across valleys	378
12	Stratified flow over three-dimensional topography: linear theory	390
12.1	Linear theory for small-amplitude topography, with the lower boundary as a stream surface	391
12.2	Linear theory for trapped lee waves	414
12.3	Atmospheric lee waves	419
12.4	Limitations and extensions of linear theory	424
13	Three-dimensional stratified flow over finite obstacles	433
13.1	The topology of the flow field on the surface of an obstacle	433
13.2	Observations of the flow past three-dimensional obstacles	439
13.3	Flow properties for finite Nh/U : theoretical aspects	473
13.4	The drag force on isolated obstacles: $Nh/U > 1$	484

14	Flow over complex and realistic terrain in the atmosphere and ocean	486
14.1	Flow over complex terrain	486
14.2	Some atmospheric examples in the troposphere	489
14.3	Internal waves in the upper atmosphere	499
14.4	Internal waves in the deep ocean	502
14.5	Topographic effects in coastal oceanography	502
14.6	Oscillating ocean flows and tides	504
15	Applications to practical modelling of flow over complex terrain	505
15.1	Laboratory modelling	505
15.2	The natural ventilation of buildings	510
15.3	Parametrisation of the effects of sub-grid-scale orography in large-scale numerical models	510
	<i>References</i>	520
	<i>Index</i>	542