CONTENTS

.

Chapter 1 Introduction

1-1	Concepts based upon molecula	ar the	югу			•					•		2
1–2	Microscopic transport phenon	nena:	the	bo	und	lary	lay	er a	nd	visc	xosi	ty	17
1–3	The description of flow fields.				•	•	•						23
	Conservation principles												
	Propagation of disturbances .												
1–6	Dynamic similitude												38
	Remarks												

Chapter 2 Thermodynamic Properties of Fluids

2-1	The fluid as a thermo	dyr	am	ic n	nedi	um	•		•					-	-	- 46
2-2	Classical thermodyna	mie	s:	the	first	t lav	v				•.					49
2–3	Some deductions from	ı th	e çe	omt	oine	d la	ws:	the	erm	ody	/na	mic	rela	atio	ns	59
24	The equation of state															63
2–5	Barotropicity															76
2–6	The speed of sound			-												82

Chapter 3 Kinematical Relations in Fluid Flows

.

3-1	Fluid motion and Eulerian representation									87
3–2	Fluid motion and deformation									93
3–3	Intrinsic coordinates							ż		102
3-4	Conservation of mass	÷							·	105
3–5	Vorticity and Helmholtz's equation							·	·	
3–6	Irrotational flow: velocity potential				ż			-		126
3–7	The general potential equation						•	-	•	129
3–8	Differential equation of the streamfunction	i: i	rrot	atic	mal	flo	w	·	•	133
3 9 .	Kinematic boundary conditions					40	**	•	•	
		·	•	•	•	•	•	•	•	150
	Appendix 3A									151
	· · · · ·									
	Appendix 3B					•	•	·	·	154

xi

xii CONTENTS

Chapter 4 Dynamical Relations in Fluid Flows

4–1	Stresses in a fluid element				-		•	•	•			156
4-2	External forces: gravitation .					•						166
4–3	Euler's momentum theorem .		•								-	171
4-4	Equations of motion									•	•	173
4–5	Forces on immersed bodies .											181
4–6	Moment of momentum										•	188
4-7	The energy equation										-	1 91
4–8	Entropy gradient and vorticity	•		•	,	•	•	•		•	·	202
	Appendix 4A	•	· ·				·					210

Chapter 5 Hydrodynamics: Theorems and Elementary Flows

5–1	The fundamental equations				212
5-2	Irrotational acyclic and cyclic motions				214
53	Properties of harmonic functions: potential theory				
5-4	Kinetic energy of an incompressible fluid flow				225
5-5					228
5-6	Elementary flows				230
5–7	Poisson's equation and rotational flow				251
5-8	Complex functions and planar, incompressible flows .				260
5–9	Further examples of flow mapping: flow over a wedge				266
5-10					273
5-11	Harmonic analysis				275
5-12	Closing remarks				280
	Appendix 5A			•	284
	Appendix 5B	•	٠		286
Chapter 6	Compressible Inviscid Fluid Flows				

6-1	The fundamental equations			•		289
6–2	Potential flow and the characteristics	-				290
6-3	Elementary phenomena of gas dynamics: shock waves					295
	The theory of sound					305
	Linearized, compressible, potential flow					
6-6	Linearized, steady, supersonic flow: thin airfoil theory	•				317
6–7	Slender-body theory					329
6-8	Reciprocity relations		-			337
6–9						
	Appendix 6A	•	•	•	•	350

Chapter 7 Viscous Fluid Flows

7–1	The fundamental equations						353
7–2	The Navier-Stokes equations: similarity	•	•				356

		o	ON	TS		xi ii	
7–3	The laminar boundary layer						361
74	The thermal boundary layer and heat transfer						375
7-5	Laminar boundary-layer stability and transition .						380
	Closing remarks						383
	Appendix 7A						385
apter 8	Mathematics Review						
8-1	Vector algebra and definitions						386
8-2	The line differential						391
8-3	The symbolic operator ∇ (del)						392
8-4	Topological considerations						402
8-5	Exact differentials	• .					403
86	Stokes's theorem						405
8–7	Gauss's theorem						407
8-8						-	410
8-9	The complex variable and complex functions						411
8–10	Conformal mapping	•	•	•	•	•	420
	Index						429