## **Fluid Mechanics**

2nd edition

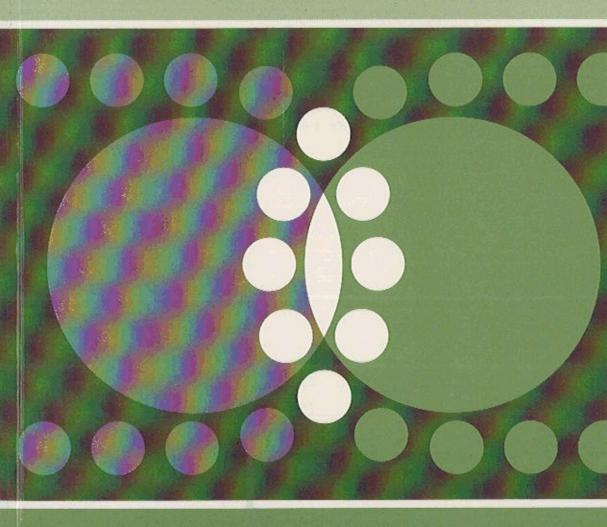
Landau and Lifshitz

Course of Theoretical Physics

Volume 6

## L.D. Landau and E.M. Lifshitz

Institute of Physical Problems, USSR Academy of Sciences, Moscow



## **CONTENTS**

	tes to the English editions	ix/x
	Lifshitz	xi xiii
Notat	ion	XIII
	I. IDEAL FLUIDS	•
§1.	The equation of continuity	1
§2.	Euler's equation	2
§3.	Hydrostatics	5 7
§4.	The condition that convection be absent	
§5.	Bernoulli's equation	8
§6.	The energy flux	9
§7.	The momentum flux	11
§8.	The conservation of circulation	12
<b>§9</b> .	Potential flow	14
§10.	Incompressible fluids	17
§11.	The drag force in potential flow past a body	26
§12.	· · · · · · · · · · · · · · · · · · ·	31
§13.	Internal waves in an incompressible fluid	37
§14.	Waves in a rotating fluid	40
	II. VISCOUS FLUIDS	
§15.	The equations of motion of a viscous fluid	44
§16.	Energy dissipation in an incompressible fluid	50
§17.	Flow in a pipe	51
§18.	Flow between rotating cylinders	55
§19.	The law of similarity	56
§20.	Flow with small Reynolds numbers	58
§21.	The laminar wake	67
§22.	The viscosity of suspensions	73
§23.	Exact solutions of the equations of motion for a viscous fluid	75
§24.	Oscillatory motion in a viscous fluid	83
§25.	Damping of gravity waves	92
	III. TURBULENCE	
§26.	Stability of steady flow	95
§27.	Stability of rotary flow	99
§28.	Stability of flow in a pipe	103
§29.	Instability of tangential discontinuities	106
§30.	Quasi-periodic flow and frequency locking	108
§31.	Strange attractors	. 113
§32.	Transition to turbulence by period doubling	118

vi Contents

§33.	Fully developed turbulence	129
§34.	The velocity correlation functions	135
§35.	The turbulent region and the phenomenon of separation	146
§36.	The turbulent jet	147
§37.	The turbulent wake	152
§38.	Zhukovskii's theorem	153
	IV. BOUNDARY LAYERS	
§39.	The laminar boundary layer	157
§40.	Flow near the line of separation	163
§41.	Stability of flow in the laminar boundary layer	167
§42.	The logarithmic velocity profile	172
§43.	Turbulent flow in pipes	176
§44.	The turbulent boundary layer	178
§45.	The drag crisis	180
§46.	Flow past streamlined bodies	183
§47.	Induced drag	185
§48.	The lift of a thin wing	189
	V. THERMAL CONDUCTION IN FLUIDS	
§49.	The general equation of heat transfer	192
§50.	Thermal conduction in an incompressible fluid	196
§51.	Thermal conduction in an infinite medium	200
§52.	Thermal conduction in a finite medium	203
§53.	The similarity law for heat transfer	208
§54.	Heat transfer in a boundary layer	210
§55.	Heating of a body in a moving fluid	214
§56.	Free convection	217
§57.	Convective instability of a fluid at rest	221
	VI. DIFFUSION	
§58.	The equations of fluid dynamics for a mixture of fluids	227
§59.	and the same of th	230
§60.		235
	VII. SURFACE PHENOMENA	
§61.	Laplace's formula	238
§62.		244
§63.	· · · · · · · · · · · · · · · · · · ·	248
	VIII. SOUND	
§ <b>64</b> .	Sound waves	251
§65.		2,55
§66.	· · · · · · · · · · · · · · · · · · ·	259
§67.		260
§68.		263
§69.	and the second s	260
-	•	

	Contents	vii
§70.	Spherical waves	269
§70.	Cylindrical waves	271
§72.	The general solution of the wave equation	273
§73.	The lateral wave	276
§74,	The emission of sound	281
§75.	Sound excitation by turbulence	289
§76.	The reciprocity principle	292
§77.	Propagation of sound in a tube	294
§78.	Scattering of sound	297
§79.	Absorption of sound	300
§80.	Acoustic streaming	305
§81.	Second viscosity	308
	IX. SHOCK WAVES	
§82.	Propagation of disturbances in a moving gas	313
§83.	Steady flow of a gas	316
§84.	Surfaces of discontinuity	320
§85.	The shock adiabatic	324
§86.	Weak shock waves	327
§87.	The direction of variation of quantities in a shock wave	329
§88.	Evolutionary shock waves	331
§89.	Shock waves in a polytropic gas	333
§90.	Corrugation instability of shock waves	336
§91.	Shock wave propagation in a pipe	343
•	Oblique shock waves	345
§93.	The thickness of shock waves	350
§94.		355
§95.	the control of the co	356
§96.	Weak discontinuities	358
	X. ONE-DIMENSIONAL GAS FLOW	
§97.		361
§98.	Flow of a viscous gas in a pipe	364
§99.	One-dimensional similarity flow	366
§100.	Discontinuities in the initial conditions	373
§101.	One-dimensional travelling waves	378
§102.	Formation of discontinuities in a sound wave	385
§103.		391
§104.		394
§105.		397
§106.		403
§107.	, , ,	406
§108.	Shallow-water theory	411
	XI. THE INTERSECTION OF SURFACES OF DISCONTINUITY	
§109.	Rarefaction waves	414
§110.		419

nii	Contents	

	0111	771 1 4 1 2 4 1 4 1 4 1 4 1 4 1 4 1 4 1 4	125
	§111.	The intersection of shock waves with a solid surface	425
	§112.	Supersonic flow round an angle	427
	§113.	Flow past a conical obstacle	432
		XII. TWO-DIMENSIONAL GAS FLOW	
	§114.	Potential flow of a gas	435
	§115.	Steady simple waves	438
	§116.	Chaplygin's equation: the general problem of steady two-dimensional	
		gas flow	442
	§117.	Characteristics in steady two-dimensional flow	445
	§118.	The Euler-Tricomi equation. Transonic flow	447
	§119.	Solutions of the Euler-Tricomi equation near non-singular points of	
		the sonic surface	452
	§120.	Flow at the velocity of sound	456
	§121.	The reflection of a weak discontinuity from the sonic line	461
		XIII. FLOW PAST FINITE BODIES	
	§122.	The formation of shock waves in supersonic flow past bodies	467
,	§122. §123.	Supersonic flow past a pointed body	470
	§123. §124.	Subsonic flow past a thin wing	474
	§125.	Supersonic flow past a wing	476
	§126.	The law of transonic similarity	479
	§123.	The law of hypersonic similarity	481
		XIV. FLUID DYNAMICS OF COMBUSTION	
	6140	Class combustion	484
	§128.	Slow combustion	489
	§129.	Detonation The proposition of a detonation wave	494
	§130.	The propagation of a detonation wave  The relation between the different modes of combustion	500
	§131.	Condensation discontinuities	503
	§132.	Condensation discontinuities	303
		XV. RELATIVISTIC FLUID DYNAMICS	
	§133.	The energy-momentum tensor	505
	§134.	The equations of relativistic fluid dynamics	506
	§135.	Shock waves in relativistic fluid dynamics	510
	§136.	Relativistic equations for flow with viscosity and thermal conduction	512
		XVI. DYNAMICS OF SUPERFLUIDS	٠
	§137.	Principal properties of superfluids	515
	§137.	The thermo-mechanical effect	517
	§130.	The equations of superfluid dynamics	518
	§130.	Dissipative processes in superfluids	523
	§140.	The propagation of sound in superfluids	526
	3- 121	t- Y Quitte	
	Index		533