

# THEORY OF FLIGHT

*by*

RICHARD VON MISES

WITH THE COLLABORATION OF W. PRAGER  
*and* GUSTAV KUERTI

WITH A NEW INTRODUCTION  
*by* KURT H. HOHENEMSER

DOVER PUBLICATIONS, INC.  
NEW YORK

This One



H9AS-TFW-Z2TC

# CONTENTS

	PAGE
PREFACE. . . . .	31

## *Part One*

### EQUILIBRIUM AND STEADY FLOW IN THE ATMOSPHERE

#### CHAPTER I. THE ATMOSPHERE AT REST

1. Density. Pressure. Equation of State . . . . .	1
2. Equilibrium of a Perfect Gas under the Influence of Gravity. . . . .	4
3. The Standard Atmosphere . . . . .	8
4. Determination of True Altitude. Reduction of a Climb to Standard Atmosphere . . . . .	13
5. Troposphere and Stratosphere. Influence of Humidity . . . . .	18

#### CHAPTER II. BERNOULLI'S EQUATION. ROTATION AND CIRCULATION

1. Steady Motion . . . . .	22
2. Bernoulli's Equation. . . . .	26
3. Dynamic Pressure. . . . .	31
4. Variation of Total Head across the Streamlines. Rotation . . . . .	35
5. Circulation and Rotation. . . . .	39
6. The Bicirculating Motion . . . . .	45

#### CHAPTER III. MOMENTUM AND ENERGY EQUATIONS

1. Flux of Momentum in Steady Flow . . . . .	52
2. Momentum Equation for Steady Flow. . . . .	55
3. Moment of Momentum . . . . .	58
4. Quasi-steady Flow. Relative Flow . . . . .	63
5. Energy Equation . . . . .	67

#### CHAPTER IV. PERFECT AND VISCOUS FLUIDS. TYPES OF FLOW

1. Viscosity. . . . .	74
2. Law of Similitude. Reynolds Number. . . . .	77
3. Laminar and Turbulent Motion. . . . .	81
4. Continuous and Discontinuous Motion. . . . .	85
5. Boundary Layer. . . . .	90

#### CHAPTER V. AIR RESISTANCE, OR PARASITE DRAG

1. Definitions. . . . .	95
2. Bluff Bodies . . . . .	96
3. Round Bodies. . . . .	99
4. Streamlined Bodies . . . . .	102
5. Skin Friction. . . . .	105
6. Parasite Drag of Major Airplane Components. . . . .	107

*Part Two*

## THE AIRPLANE WING

## CHAPTER VI. FUNDAMENTAL NOTIONS. GEOMETRY OF WINGS

	Page
1. The Three Coefficients. . . . .	112
2. Geometry of Airfoil Profiles. Sets of Profiles. . . . .	115
3. Theoretically Developed Airfoil Sections. . . . .	121
4. Geometry of Airplane Wings . . . . .	132

## CHAPTER VII. EMPIRICAL AIRFOIL DATA

1. The Three Main Results. . . . .	139
2. Influence of Aspect Ratio . . . . .	148
3. Historical Development of Wing Profiles. . . . .	157
4. Influence of the Shape of the Profile. . . . .	161
5. Influence of the Reynolds Number. Degree of Turbulence. . . . .	167

## CHAPTER VIII. THE WING OF INFINITE SPAN

1. The Momentum Equation for Irrotational Flow. . . . .	170
2. The Lift on an Airfoil of Infinite Span. . . . .	174
3. The Pitching Moment of an Airfoil of Infinite Span . . . . .	181
4. The Metacentric Parabola . . . . .	186
5. Vortex Sheets, Another Approach. . . . .	188
6. Theory of Thin Airfoils . . . . .	198

## CHAPTER IX. THE WING OF FINITE SPAN

1. Curved Vortex Lines. . . . .	211
2. Vortex Sheet and Discontinuity Surface . . . . .	216
3. The Flow Past a Wing of Finite Span . . . . .	224
4. Prandtl's Wing Theory. . . . .	231
5. Elliptic Lift Distribution. . . . .	239
6. Biplane Theory. . . . .	244
7. General Lift Distribution. . . . .	250

## CHAPTER X. ADDITIONAL FACTS ABOUT WINGS

1. Stalling . . . . .	258
2. High-lift Devices . . . . .	264
3. Pressure Distribution . . . . .	271
4. Influence of Compressibility . . . . .	275

*Part Three*

## PROPELLER AND ENGINE

## CHAPTER XI. THE PROPELLER

1. Basic Concepts. . . . .	285
2. Geometry of Propellers. . . . .	290
3. Propeller Characteristics. . . . .	296
4. Quantitative Analysis . . . . .	302
5. Propeller Sets and Variable-pitch Propeller. Propeller Charts . . . . .	310

## CHAPTER XII. OUTLINE OF PROPELLER THEORY

	PAGE
1. Blade-element Theory . . . . .	317
2. Momentum Theory, Basic Relations . . . . .	326
3. Momentum Theory, Conclusions . . . . .	334
4. Modified Momentum Theory . . . . .	339
5. The Two Theories Combined . . . . .	345
6. Additional Remarks . . . . .	350

## CHAPTER XIII. THE AIRPLANE ENGINE

1. The Engine at Sea Level . . . . .	356
2. The Engine at Altitude . . . . .	364
3. Engine Vibrations . . . . .	371

*Part Four*

## AIRPLANE PERFORMANCE

## CHAPTER XIV. THE GENERAL PERFORMANCE PROBLEM

1. Introduction . . . . .	381
2. Power-required and Power-available Curves . . . . .	385
3. Dimensionless Performance Analysis . . . . .	394
4. Discussion of Sea-level Flight . . . . .	398
5. Altitude Flight . . . . .	409

## CHAPTER XV. ANALYTICAL METHODS OF PERFORMANCE COMPUTATION

1. Analytic Expressions for the Power Curves . . . . .	419
2. Gliding. Level Flight with Given Power . . . . .	427
3. The Ideal Airplane: Power Available Independent of Speed . . . . .	437
4. Numerical Data. Example . . . . .	442
5. Small Variations. Choice of Propeller . . . . .	447
6. Power Available Varying with Speed . . . . .	450
7. Numerical Discussion . . . . .	455

## CHAPTER XVI. SPECIAL PERFORMANCE PROBLEMS

1. Range and Endurance . . . . .	461
2. Take-off . . . . .	469
3. Steep Gliding and Diving . . . . .	475
4. Landing Operation. Landing Impact . . . . .	483
5. Seaplane Problems . . . . .	488

*Part Five*

## AIRPLANE CONTROL AND STABILITY

## CHAPTER XVII. MOMENT EQUILIBRIUM AND STATIC STABILITY

1. Pitching-moment Equilibrium . . . . .	497
2. The Contribution to the Pitching Moment from the Tail . . . . .	501
3. The Contribution from the Propeller and the Fuselage . . . . .	507
4. Static Stability and Metacenter . . . . .	514
5. Simplified Stability Discussion . . . . .	522
6. Lateral Moments . . . . .	527

## CHAPTER XVIII. NONUNIFORM FLIGHT

	Page
1. Introduction. Elementary Results . . . . .	533
2. Lanchester's Phugoid Theory. . . . .	539
3. Longitudinal Flight along a Given Path . . . . .	545
4. Effect of Elevator Operation . . . . .	551
5. Asymmetric Motion. . . . .	555

## CHAPTER XIX. GENERAL THEORY OF MOTION AND STABILITY

1. The General Equations of Motion of an Airplane . . . . .	564
2. Steady Motion. Specification of Forces . . . . .	570
3. Theory of Dynamic Stability. . . . .	574
4. Application to the Airplane. . . . .	580

## CHAPTER XX. DYNAMIC STABILITY OF AN AIRPLANE

1. Longitudinal Stability of Level Flight . . . . .	586
2. The Small Oscillations Following a Disturbance. . . . .	593
3. Lateral Stability . . . . .	599
4. Numerical Discussion . . . . .	603
5. Final Remarks. Autorotation. Spinning . . . . .	608

BIBLIOGRAPHICAL AND HISTORICAL NOTES. . . . .	614
---	-----

INDEX . . . . .	621
-----------------	-----