MATHEMATICAL MONOGRAPHS NO. 21. THE DYNAMICS OF THE AIRPLANE

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649566235

Mathematical Monographs No. 21. The Dynamics of the Airplane by Kenneth P. Williams & Mansfield Merriman & Robert S. Woodward

Except for use in any review, the reproduction or utilisation of this work in whole or in part in any form by any electronic, mechanical or other means, now known or hereafter invented, including xerography, photocopying and recording, or in any information storage or retrieval system, is forbidden without the permission of the publisher, Trieste Publishing Pty Ltd, PO Box 1576 Collingwood, Victoria 3066 Australia.

All rights reserved.

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out, or otherwise circulated without the publisher's prior consent in any form or binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

www.triestepublishing.com

KENNETH P. WILLIAMS &
MANSFIELD MERRIMAN & ROBERT S. WOODWARD

MATHEMATICAL MONOGRAPHS NO. 21. THE DYNAMICS OF THE AIRPLANE

Trieste

MATHEMATICAL MONOGRAPHS

EDITED BY

Mansfield Merriman and Robert S. Woodward

Octavo, Cloth

No. 1. History of Modern Mathematics.
By DAVID EUGENE SMITH. $1.25 *net.*

No. 2. Synthetic Projective Geometry.
By GEORGE BRUCE HALSTED. $1.25 *net.*

No. 3. Determinants.
By LAENAS GIFFORD WELD. $1.25 *net.*

No. 4. Hyperbolic Functions.
By JAMES MCMAHON. $1.25 *net.*

No. 5. Harmonic Functions.
By WILLIAM E. BYERLY. $1.25 *net.*

No. 6. Grassmann's Space Analysis.
By EDWARD W. HYDE. $1.25 *net.*

No. 7. Probability and Theory of Errors.
By ROBERT S. WOODWARD. $1.25 *net.*

No. 8. Vector Analysis and Quaternions.
By ALEXANDER MACFARLANE. $1.25 *net.*

No. 9. Differential Equations.
By WILLIAM WOOLSEY JOHNSON. $1.50. *net.*

No. 10. The Solution of Equations.
By MANSFIELD MERRIMAN. $1.25 *net.*

No. 11. Functions of a Complex Variable.
By THOMAS S. FISKE. $1.25 *net.*

No. 12. The Theory of Relativity.
By ROBERT D. CARMICHAEL. $1.25 *net.*

No. 13. The Theory of Numbers.
By ROBERT D. CARMICHAEL. $1.25 *net.*

No. 14. Algebraic Invariants.
By LEONARD E. DICKSON. $1.50 *net.*

No. 15. Mortality Laws and Statistics.
By ROBERT HENDERSON. $1.50 *net.*

No. 16. Diophantine Analysis.
By ROBERT D. CARMICHAEL. $1.50 *net.*

No. 17. Ten British Mathematicians.
By ALEXANDER MACFARLANE. $1.50 *net.*

No. 18. Elliptic Integrals.
By HARRIS HANCOCK. $1.50 *net.*

No. 19. Empirical Formulas.
By THEODORE R. RUNNING. $1.50 *net.*

No. 20. Ten British Physicists.
By ALEXANDER MACFARLANE. $1.50 *net.*

No. 21. The Dynamics of the Airplane.
By KENNETH P. WILLIAMS. $2.50 *net.*

PUBLISHED BY

JOHN WILEY & SONS, Inc., NEW YORK

CHAPMAN & HALL, Limited, LONDON

MATHEMATICAL MONOGRAPHS
EDITED BY
MANSFIELD MERRIMAN AND ROBERT S. WOODWARD

No. 21

THE DYNAMICS OF THE AIRPLANE

BY
KENNETH P. WILLIAMS, PH.D.
ASSOCIATE PROFESSOR OF MATHEMATICS
INDIANA UNIVERSITY

NEW YORK
JOHN WILEY & SONS, INC.
LONDON: CHAPMAN & HALL, LIMITED
1921

COPYRIGHT, 1921
BY
K. P. WILLIAMS

PRESS OF
BRAUNWORTH & CO.
BOOK MANUFACTURERS
BROOKLYN, N. Y.

24 24480
FEB 18 1921
STS
.W67

318/2560

PREFACE

It was the good fortune of the author to attend the University of Paris during the spring semester of 1919. One of the special courses which the French authorities, with their characteristic hospitality, arranged for the large number of students from the American army, was a course in aërodynamics, given by Professor Marchis. The comprehensive knowledge that Professor Marchis possessed of all branches of the new science of aëronautics, the inestimable value of his advice to the French Republic during the war, the interest he took in his rather unusual class, could not fail to be an inspiration.

This book is an outgrowth of those parts of Professor Marchis' lectures that were of particular interest to the author. It is in no sense a complete treatise on aviation. Questions of design and construction are passed over with bare mention. The book is intended for students of mathematics and physics who are attracted by the dynamical aspect of aviation. The problems presented by the motion of an airplane are novel and fascinating. They vary from the most pleasing simplicity to the most stimulating difficulty. The question of stability, particularly, exhibits at the same time the elegance and the power of analysis, and shows the adaptability of some of the general developments in dynamics. The field is assuredly a fruitful one of study, and increasing demands will be put upon the mathematician as the science of aviation continues its rapid development. The mathematician can well own a sense of pride that he had already at hand, in the developments inaugurated by Euler and Routh, a means of dealing accurately with the question of stability, that plays so fundamental a rôle in the science of flying.

The treatment in the text is for the most part elementary. The last chapter alone demands of the student familiarity with more advanced dynamical methods. In the treatment of descent a slight digression is made to consider in part the nature of the solution of a system of two differential equations. This was done in order not to completely evade what seems a problem of considerable difficulty. It might seem that a treatment of the propeller should not find a place in a book with the purpose of this one. No student of mathematics, however, could fail to own a curiosity as to a propeller's action, and it is hoped the discussion, while not complete, will at least serve as a sufficient introduction.

The various curves in the text were plotted by Mr. R. W. Smith, a former student in this university. The author is further indebted to the Smithsonian Institution for permission to use Figs. 12 and 49.

In addition to the various books that are referred to in the text the author has made use of his notes of the lectures of Professor Marchis, translated into English by Madame Ciolkowska, who rendered most valuable aid as an interpreter for those who understood and spoke the language of Professor Marchis only with difficulty.

K. P. WILLIAMS.

Indiana University,
July, 1920.

CONTENTS

CHAPTER I. THE PLANE AND CAMBERED SURFACE

ARTICLE		PAGE
1, 2.	Preliminary Considerations	1–3
3.	Pressure on a Plane	4
4.	The Inclined Plane	5
5.	The Center of Pressure	6
6.	Aspect Ratio	6
7.	The Cambered Wing	7
8.	Characteristic Curves for a Given Wing	8, 9
9.	Polar Diagram	10
10.	Effect of Variation of Wing Elements	11
11.	Pressure over the Wing	11
12.	Center of Pressure	12
13.	Relation between K_y and K_x	13
14.	The Biplane	14
15.	Body Resistance	15
16.	Experiments on Complete Model	15

CHAPTER II. STRAIGHT HORIZONTAL FLIGHT

17.	Preliminary Considerations	18
18.	Horizontal Flight	19
19.	The Velocity	20
20.	Landing Speed	20
21.	Effect of Altitude	21
22.	The Effort of Traction	22
23.	Opt mum Angle	22
24.	Fineness	23
25.	Optimum Angle, Continued	24
26, 27.	Useful Power	25
28, 29.	Economical Angle	26–28
30.	General Considerations	29

CHAPTER III. DESCENT AND ASCENT

1. Descent

31.	Preliminary Considerations Concerning Descent	31
32.	Equations of Motion	31

ARTICLE PAGE
33, 34. RECTILINEAR DESCENT 33–35
35. GENERAL RESULTS CONCERNING DESCENT 36
36–38. DESCENT CONSIDERING AIR DENSITY CONSTANT 38–42

2. ASCENT

39. PRELIMINARY CONSIDERATIONS CONCERNING ASCENT 43
40. EQUATIONS OF MOTION FOR ASCENT 43
41. VELOCITY ALONG PATH 44
42. THE FORCE OF TRACTION 44
43. THE POWER NECESSARY 46
44. THE VERTICAL VELOCITY 47
45. GENERAL CONSIDERATIONS 48
46. EXPERIMENTAL LAW OF VERTICAL VELOCITY 49
47. TIME OF ASCENT 50
48. DETERMINATION OF THE CEILING 50

CHAPTER IV. CIRCULAR FLIGHT

1. HORIZONTAL TURNS

49. GENERAL CONSIDERATIONS 52
50. EQUATIONS OF MOTION 53
51. VELOCITY AND INCLINATION 54
52. THE TRACTION AND POWER 55
53. ACTION OF CONTROLS 56

2. CIRCULAR DESCENT

54. GENERAL CONSIDERATIONS 58
55. EQUATIONS OF MOTION 59
56. RELATIONS BETWEEN ANGLES USED 60
57. OTHER FORM OF EQUATIONS OF MOTION 61
58. IDENTITY OF TWO FORMS OF EQUATIONS OF MOTION 62
59. DETERMINATION OF ANGLES SPECIFYING MOTION 63–65
60. THE VELOCITY 66

CHAPTER V. THE PROPELLER

61–64. GENERAL CONSIDERATIONS 69, 70
65. GEOMETRICAL PITCH 71
66–68. THE THRUST AND POWER 74–76
69. EFFICIENCY 77
70. EFFECT OF ALTITUDE 77
71, 72. GRAPHS OF PROPELLER COEFFICIENTS 78
73. MOTOR DIAGRAM 81
74–78. ADAPTATION OF MOTOR-PROPELLER GROUP TO MACHINE 82–85