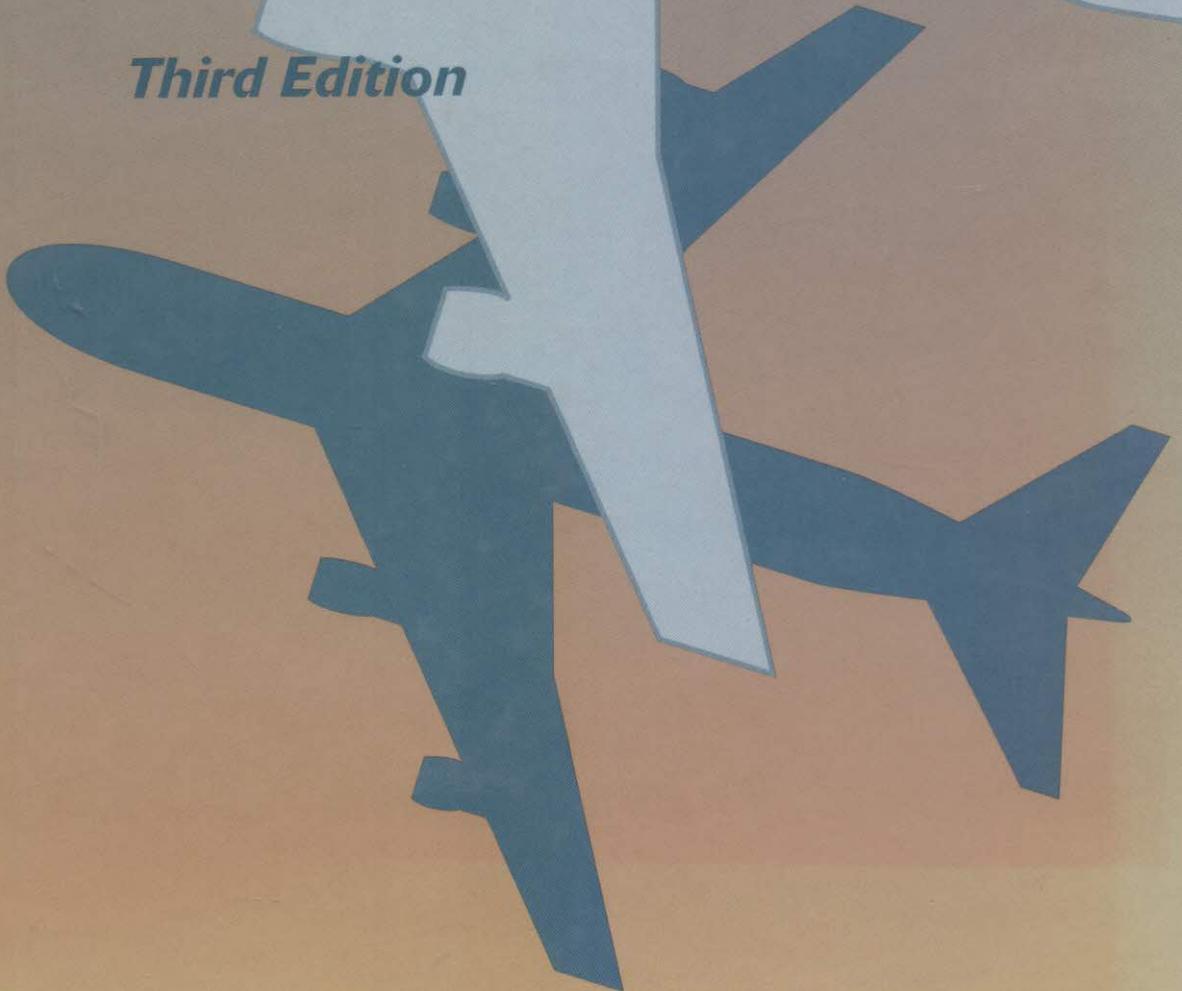


Bernard Etkin
Lloyd Duff Reid

DYNAMICS ***of FLIGHT***

Stability and Control

Third Edition



C O N T E N T S

CHAPTER 1 *Introduction*

- 1.1 The Subject Matter of Dynamics of Flight 1
- 1.2 The Tools of Flight Dynamicists 5
- 1.3 Stability, Control, and Equilibrium 6
- 1.4 The Human Pilot 8
- 1.5 Handling Qualities Requirements 11
- 1.6 Axes and Notation 15

CHAPTER 2 *Static Stability and Control—Part 1*

- 2.1 General Remarks 18
- 2.2 Synthesis of Lift and Pitching Moment 23
- 2.3 Total Pitching Moment and Neutral Point 29
- 2.4 Longitudinal Control 33
- 2.5 The Control Hinge Moment 41
- 2.6 Influence of a Free Elevator on Lift and Moment 44
- 2.7 The Use of Tabs 47
- 2.8 Control Force to Trim 48
- 2.9 Control Force Gradient 51
- 2.10 Exercises 52
- 2.11 Additional Symbols Introduced in Chapter 2 57

CHAPTER 3 *Static Stability and Control—Part 2*

- 3.1 Maneuverability-Elevator Angle per g 60
- 3.2 Control Force per g 63
- 3.3 Influence of High-Lift Devices on Trim and Pitch Stiffness 64
- 3.4 Influence of the Propulsive System on Trim and Pitch Stiffness 66
- 3.5 Effect of Structural Flexibility 72
- 3.6 Ground Effect 74
- 3.7 CG Limits 74
- 3.8 Lateral Aerodynamics 76
- 3.9 Weathercock Stability (Yaw Stiffness) 77
- 3.10 Yaw Control 80
- 3.11 Roll Stiffness 81
- 3.12 The Derivative $C_{l\beta}$ 83
- 3.13 Roll Control 86
- 3.14 Exercises 89
- 3.15 Additional Symbols Introduced in Chapter 3 91

CHAPTER 4 *General Equations of Unsteady Motion*

- 4.1 General Remarks 93
- 4.2 The Rigid-Body Equations 93

4.3	Evaluation of the Angular Momentum \mathbf{h}	96
4.4	Orientation and Position of the Airplane	98
4.5	Euler's Equations of Motion	100
4.6	Effect of Spinning Rotors on the Euler Equations	103
4.7	The Equations Collected	103
4.8	Discussion of the Equations	104
4.9	The Small-Disturbance Theory	107
4.10	The Nondimensional System	115
4.11	Dimensional Stability Derivatives	118
4.12	Elastic Degrees of Freedom	120
4.13	Exercises	126
4.14	Additional Symbols Introduced in Chapter 4	127

CHAPTER 5 *The Stability Derivatives*

5.1	General Remarks	129
5.2	The α Derivatives	129
5.3	The u Derivatives	131
5.4	The q Derivatives	135
5.5	The $\dot{\alpha}$ Derivatives	141
5.6	The β Derivatives	148
5.7	The p Derivatives	149
5.8	The r Derivatives	153
5.9	Summary of the Formulas	154
5.10	Aeroelastic Derivatives	156
5.11	Exercises	159
5.12	Additional Symbols Introduced in Chapter 5	160

CHAPTER 6 *Stability of Uncontrolled Motion*

6.1	Form of Solution of Small-Disturbance Equations	161
6.2	Longitudinal Modes of a Jet Transport	165
6.3	Approximate Equations for the Longitudinal Modes	171
6.4	General Theory of Static Longitudinal Stability	175
6.5	Effect of Flight Condition on the Longitudinal Modes of a Subsonic Jet Transport	177
6.6	Longitudinal Characteristics of a STOL Airplane	184
6.7	Lateral Modes of a Jet Transport	187
6.8	Approximate Equations for the Lateral Modes	193
6.9	Effects of Wind	196
6.10	Exercises	201
6.11	Additional Symbols Introduced in Chapter 6	203

CHAPTER 7 *Response to Actuation of the Controls—Open Loop*

7.1	General Remarks	204
7.2	Response of Linear/Invariant Systems	207
7.3	Impulse Response	210

7.4	Step-Function Response	213
7.5	Frequency Response	214
7.6	Longitudinal Response	228
7.7	Responses to Elevator and Throttle	229
7.8	Lateral Steady States	237
7.9	Lateral Frequency Response	243
7.10	Approximate Lateral Transfer Functions	247
7.11	Transient Response to Aileron and Rudder	252
7.12	Inertial Coupling in Rapid Maneuvers	256
7.13	Exercises	256
7.14	Additional Symbols Introduced in Chapter 7	258

CHAPTER 8 *Closed-Loop Control*

8.1	General Remarks	259
8.2	Stability of Closed Loop Systems	264
8.3	Phugoid Suppression: Pitch Attitude Controller	266
8.4	Speed Controller	270
8.5	Altitude and Glide Path Control	275
8.6	Lateral Control	280
8.7	Yaw Damper	287
8.8	Roll Controller	290
8.9	Gust Alleviation	295
8.10	Exercises	300
8.11	Additional Symbols Introduced in Chapter 8	301

APPENDIX A *Analytical Tools*

A.1	Linear Algebra	303
A.2	The Laplace Transform	304
A.3	The Convolution Integral	309
A.4	Coordinate Transformations	310
A.5	Computation of Eigenvalues and Eigenvectors	315
A.6	Velocity and Acceleration in an Arbitrarily Moving Frame	316

APPENDIX B *Data for Estimating Aerodynamic Derivatives* 319

APPENDIX C *Mean Aerodynamic Chord, Mean Aerodynamic Center, and C_{mac_w}* 357

APPENDIX D *The Standard Atmosphere and Other Data* 364

APPENDIX E *Data For the Boeing 747-100* 369

References 372

Index 377