## Contents

List of Symbols

Chapter I Introduction and Motivation	1					
1 Basic Concepts 2 Mathematical Formulation of the Control Problem 3 Controllability 4 Optimal Control 5 The Rocket Car Exercises Notes						
					Chapter II Controllability	24
					1 Introduction: Some Simple General Results	24
					2 The Linear Case	28
					3 Controllability for Nonlinear Autonomous Systems	38
					4 Special Controls	44
					Exercises	48
Appendix: Proof of the Bang-Bang Principle	50					
Chapter III Linear Autonomous Time-Optimal Control Problems	57					
1 Introduction: Summary of Results	57					
2 The Existence of a Time-Optimal Control; Extremal Controls; the Bang-Bang Principle	60					

хi

Contents

x

<b>A. 3.2</b>	
3 Normality and the Uniqueness of the Optimal Control	65
4 Applications	74
5 The Converse of the Maximum Principle	77
6 Extensions to More General Problems Exercises	79
Exercises	80
Chapter IV	
Existence Theorems for Optimal Control Problems	82
1 Introduction	82
2 Three Discouraging Examples. An Outline of the Basic Approach to Existence Proofs	82
3 Existence for Special Control Classes	83
4 Existence Theorems under Convert	88
<ul><li>4 Existence Theorems under Convexity Assumptions</li><li>5 Existence for Systems Linear in the State</li></ul>	91
6 Applications	97
Exercises	98
Notes	100 102
Chapter V Necessary Conditions for Optimal Controls—The Pontryagin	
Maximum Principle	103
1 Introduction	103
2 The Pontryagin Maximum Principle for Autonomous Systems	103
3 Applying the Maximum Principle	111
4 A Dynamic Programming Approach to the Proof of the Maximum	
Tinciple	118
5 The PMP for More Complicated Problems	124
Exercises	128
Appendix to Chapter V—A Proof of the Pontryagin Maximum	
i i incipie	134
Mathematical Appendix	147
Bibliography	160
Index	163