

## Table of Contents

<b>Preface</b>		<b>xi</b>
<b>Unit 1</b>	<b>Introduction and Overview</b>	
1-1.	Course Coverage	3
1-2.	Purpose	4
1-3.	Audience and Prerequisites	4
1-4.	Study Material	5
1-5.	Organization and Sequence	5
1-6.	Course Objectives	6
1-7.	Course Length	6
SECTION ONE: THREE BASIC CONCEPTS		
<b>Unit 2.</b>	<b>Feedback Control</b>	
2-1.	Feedback Control	11
2-2.	A Single Feedback Control Loop	13
2-3.	Block Diagrams	14
2-4.	The Functional Layout of a Feedback Loop	15
2-5.	Dynamic Components	17
2-6.	Mathematical Model of a Loop	18
2-7.	Proportional Control Action	19
2-8.	Reset Control Action	22
2-9.	Rate Control Action	24
2-10.	A Typical Tuning Method	26
	References	29
	Exercises	30
<b>Unit 3.</b>	<b>Feedforward Control</b>	
3-1.	Manual Feedforward Control	35
3-2.	Automatic Feedforward Control	36
3-3.	Feedforward Control	37
3-4.	A Feedforward Control Example	39
3-5.	Steady-State or Dynamic Feedforward Control?	41
3-6.	General Feedforward Control	42
3-7.	Combined Feedforward and Feedback Control	43
3-8.	An Example Application	46
	References	49
	Exercises	50

<b>Unit 4.</b>	<b>Sequential Control</b>	
4-1.	Sequential Control	55
4-2.	Batch Terminology	59
4-3.	Batch Process Characteristics/Benefits/Problems	61
4-4.	Sequential Logic Structure	64
4-5.	Predictive or Endpoint Control	66
	References	67
	Exercises	67

**SECTION TWO: VARIATIONS AND EXTENSIONS OF THE  
THREE BASIC CONCEPTS**

<b>Unit 5.</b>	<b>Cascade Control</b>	
5-1.	The Concept of Cascade Control	75
5-2.	Simple Applications	76
5-3.	More Complex Applications	79
5-4.	Guiding Principles for Implementing Cascade Control	84
5-5.	More Examples	90
5-6.	Selection of Cascade Controller Modes and Tuning	91
	References	94
	Exercises	94
<b>Unit 6.</b>	<b>Special Purpose Concepts</b>	
6-1.	Computing Components	99
6-2.	Ratio Control	100
6-3.	Applying Ratio Control	102
6-4.	Override Control	105
6-5.	Selective Control	110
6-6.	Duplex or Split-Range Control	113
6-7.	Auto-Selector or Cutback Control	114
	References	114
	Exercises	114
<b>Unit 7.</b>	<b>Supervisory Control and Process Management</b>	
7-1.	Process Information Systems	119
7-2.	Supervisory Control	120
7-3.	Related Applications	123
7-4.	Process Control and Process Management	124
7-5.	Specific Characteristics of Process Control Automation	124

7-6.	Specific Characteristics of Process Management	126
7-7.	Overall Control Configuration	127
7-8.	Specific Details of Control Configuration	130
7-9.	Expert Systems/Artificial Intelligence	133
	References	136
	Exercises	136

### SECTION THREE: TRULY ADVANCED CONCEPTS

#### Unit 8. Dead Time Control

8-1.	Dead Time	141
8-2.	The Smith Predictor Algorithm	144
8-3.	A Smith Predictor Application	148
8-4.	The Moore Analytic Predictor	151
8-5.	The Dahlin Algorithm	152
8-6.	Summary	153
	References	154
	Exercises	155

#### Unit 9. Nonlinear Compensation and Adaptive Control

9-1.	Nonlinearities	159
9-2.	Valve Characteristics	160
9-3.	Process Characteristics	164
9-4.	Adaptive Control	168
9-5.	Adaptive Gain Control	170
9-6.	Three-Mode On-Line Tuning	173
9-7.	Model Reference Adaptive Control	177
	References	178
	Exercises	180

#### Unit 10. Multivariable Control

10-1.	Interacting Loops	185
10-2.	The Relative Gain Array	189
10-3.	Understanding and Use of RGA	191
10-4.	Eliminating Interaction	195
10-5.	Linear Decoupling	200
10-6.	Interpretation of RGA	202
	References	203
	Exercises	204

<b>Unit 11. Optimal Control</b>	
11-1. The State Equation	211
11-2. State Equation Example	215
11-3. The Optimal Control Problem	217
11-4. The Minimum Principle	218
11-5. Minimum Principle Application	220
11-6. Dynamic Programming	223
11-7. Final Comments on Optimal Control	224
References	225
<b>APPENDIX A. Suggested Readings and Study Materials</b>	229
<b>APPENDIX B. Glossary of Standard Process Instrumentation Terminology</b>	233
<b>APPENDIX C. Symbols Used in This ILM</b>	255
<b>APPENDIX D. Solutions to All Exercises</b>	259
<b>Index</b>	281