

# ECE 580 Optimization Methods for Systems and Control

## Tentative Syllabus

The chapter and section titles, along with the chapter, section, and page numbers, refer to the text by Chong and Zak.

Part 1: Mathematical Review, Chapters 1, 2, 3, and 5, cover undergraduate mathematics. Students should carefully review these chapters to make sure that they are able to understand and use this material. Students are welcome to ask questions of the instructor regarding this material by email or by appointment. Chapter 4 will be covered in this course, as needed.

Preface .....	xiii
<b>PART I MATHEMATICAL REVIEW</b>	
<b>1 Methods of Proof and Some Notation .....</b>	<b>3</b>
1.1 Methods of Proof .....	3
1.2 Notation .....	5
Exercises .....	6
<b>2 Vector Spaces and Matrices .....</b>	<b>7</b>
2.1 Vector and Matrix .....	7
2.2 Rank of a Matrix .....	7
2.3 Linear Equations .....	13
2.4 Inner Products and Norms .....	17
Exercises .....	19
<b>3 Transformations .....</b>	<b>23</b>
3.1 Linear Transformations .....	23
3.2 Eigenvalues and Eigenvectors .....	24
3.3 Orthogonal Projections .....	27
3.4 Quadratic Forms .....	29
3.5 Matrix Norms .....	33
Exercises .....	38
<b>4 Concepts from Geometry .....</b>	<b>43</b>
4.1 Line Segments .....	43
4.2 Hyperplanes and Linear Varieties .....	44

4.3 Convex Sets .....	46
4.4 Neighborhoods .....	48
4.5 Polytopes and Polyhedra .....	50
Exercises .....	51
<b>5 Elements of Calculus .....</b>	<b>53</b>
5.1 Sequences and Limits .....	53
5.2 Differentiability .....	60
5.3 The Derivative Matrix .....	61
5.4 Differentiation Rules .....	65
5.5 Level Sets and Gradients .....	66
5.6 Taylor Series .....	70
Exercises .....	75
<b>PART II UNCONSTRAINED OPTIMIZATION</b>	
<b>6 Basics of Set-Constrained and Unconstrained Optimization .....</b>	<b>79</b>
6.1 Introduction .....	79
6.2 Conditions for Local Minimizers .....	81
Exercises .....	91
<b>7 One-Dimensional Search Methods .....</b>	<b>101</b>
7.3 Newton's Method .....	113
7.4 Secant Method .....	117
7.5 Remarks on Line Search Methods .....	119
Exercises .....	121
<b>8 Gradient Methods .....</b>	<b>125</b>
8.1 Introduction .....	125
8.2 The Method of Steepest Descent .....	125
8.3 Analysis of Gradient Methods .....	127
Exercises .....	135
<b>9 Newton's Method .....</b>	<b>155</b>
9.1 Introduction .....	155
9.2 Analysis of Newton's Method .....	158

9.3 Levenberg-Marquardt Modification .....	162
9.4 Newton's Method for Nonlinear Least Squares .....	162
Exercises .....	165
<b>10 Conjugate Direction Methods .....</b>	<b>169</b>
10.1 Introduction .....	169
10.2 The Conjugate Direction Algorithm .....	171
10.3 The Conjugate Gradient Algorithm .....	176
10.4 The Conjugate Gradient Algorithm for Nonquadratic Problems .....	180
Exercises .....	182
<b>11 Quasi-Newton Methods .....</b>	<b>187</b>
11.1 Introduction .....	187
11.2 Approximating the Inverse Hessian .....	188
11.3 The Rank One Correction Formula .....	191
11.4 The DFP Algorithm .....	196
11.5 The BFGS Algorithm .....	201
Exercises .....	205
<b>12 Solving Linear Equations .....</b>	<b>211</b>
12.1 Least-Squares Analysis .....	211
12.2 The Recursive Least-Squares Algorithm .....	221
12.3 Solution to a Linear Equation with Minimum Norm .....	225
12.4 Kaczmarz's Algorithm .....	226
12.5 Solving Linear Equations in General .....	230
Exercises .....	238
<b>14 Global Search Algorithms .....</b>	<b>267</b>
14.1 Introduction .....	267
14.2 The Nelder-Mead Simplex Algorithm .....	268
14.3 Simulated Annealing Exercises .....	272
14.4 Particle Swarm Optimization .....	276
14.5 Genetic Algorithms .....	279
Exercises .....	292

**PART III LINEAR PROGRAMMING**

<b>15 Introduction to Linear Programming</b> .....	<b>299</b>
15.1 Brief History of Linear Programming .....	299
15.2 Simple Examples of Linear Programs .....	301
15.3 Two-Dimensional Linear Programs .....	308
15.4 Convex Polyhedra and Linear Programming .....	310
15.5 Standard Form Linear Programs .....	312
15.6 Basic Solutions .....	318
15.7 Properties of Basic Solutions .....	321
15.8 Geometric View of Linear Programs .....	324
Exercises .....	329
<b>16 Simplex Method</b> .....	<b>333</b>
16.1 Solving Linear Equations Using Row Operations .....	333
16.2 The Canonical Augmented Matrix .....	340
16.3 Updating the Augmented Matrix .....	342
16.4 The Simplex Algorithm .....	343
16.5 Matrix Form of the Simplex Method .....	350
16.6 Two-Phase Simplex Method .....	354
16.7 Revised Simplex Method .....	358
Exercises .....	363
<b>17 Duality</b> .....	<b>371</b>
17.1 Dual Linear Program .....	371
17.2 Properties of Dual Problems .....	379
Exercises .....	386
<b>18 Nonsimplex Methods</b> .....	<b>395</b>
18.1 Introduction .....	395
18.2 Khachiyan's Method .....	397
18.3 Affine Scaling Method .....	400
18.4 Karmarkar's Method .....	405
Exercises .....	418

**NONLINEAR CONSTRAINED OPTIMIZATION**

<b>19 Problems with Equality Constraints</b> .....	<b>423</b>
19.1 Introduction .....	423
19.2 Problem Formulation .....	425
19.3 Tangent and Normal Spaces .....	426
19.4 Lagrange Condition .....	433
19.5 Second-Order Conditions .....	442
19.6 Minimizing Quadratics Subject to Linear Constraints .....	446
Exercises .....	450
<b>20 Problems with Inequality Constraints</b> .....	<b>457</b>
20.1 Karush-Kuhn-Tucker Condition .....	457
20.2 Second-Order Condition .....	466
Exercises .....	471
<b>21 Convex Optimization Problems</b> .....	<b>479</b>
21.1 Introduction .....	479
21.2 Convex Functions .....	482
21.3 Convex Optimization Problems .....	491
Exercises .....	506
References .....	563
Index .....	571