

Preface	1
1 Overview of Cryptography and Its Applications	1
1.1 Secure Communications	2
1.2 Cryptographic Applications	9
2 Classical Cryptosystems	12
2.1 Shift Ciphers	13
2.2 Affine Ciphers	14
2.3 The Vigenère Cipher	16
2.4 Substitution Ciphers	24
2.5 Sherlock Holmes	27
2.6 The Playfair and ADFGX Ciphers	30
2.7 Block Ciphers	34
2.8 Binary Numbers and ASCII	38
2.9 One-Time Pads	39
2.10 Pseudo-random Bit Generation	41
2.11 LFSR Sequences	43
2.12 Enigma	50
2.13 Exercises	55
2.14 Computer Problems	59
3 Basic Number Theory	63
3.1 Basic Notions	63
3.2 Solving $ax + by = d$	69
3.3 Congruences	70
3.4 The Chinese Remainder Theorem	76
3.5 Modular Exponentiation	78
3.6 Fermat and Euler	79
3.7 Primitive Roots	83
3.8 Inverting Matrices Mod n	85
3.9 Square Roots Mod n	86
3.10 Legendre and Jacobi Symbols	88
3.11 Finite Fields	93
3.12 Continued Fractions	102
3.13 Exercises	104
3.14 Computer Problems	111
4 The Data Encryption Standard	113
4.1 Introduction	113
4.2 A Simplified DES-Type Algorithm	114
4.3 Differential Cryptanalysis	118
4.4 DES	123
4.5 Modes of Operation	131

4.6	Breaking DES	139
4.7	Meet-in-the-Middle Attacks	143
4.8	Password Security	144
4.9	Exercises	146
4.10	Computer Problems	149
5	The Advanced Encryption Standard: Rijndael	151
5.1	The Basic Algorithm	152
5.2	The Layers	154
5.3	Decryption	158
5.4	Design Considerations	161
5.5	Exercises	162
6	The RSA Algorithm	164
6.1	The RSA Algorithm	164
6.2	Attacks on RSA	169
6.3	Primality Testing	176
6.4	Factoring	181
6.5	The RSA Challenge	187
6.6	An Application to Treaty Verification	189
6.7	The Public Key Concept	189
6.8	Exercises	192
6.9	Computer Problems	197
7	Discrete Logarithms	201
7.1	Discrete Logarithms	201
7.2	Computing Discrete Logs	202
7.3	Bit Commitment	209
7.4	Diffie-Hellman Key Exchange	210
7.5	The ElGamal Public Key Cryptosystem	212
7.6	Exercises	214
7.7	Computer Problems	216
8	Hash Functions	218
8.1	Hash Functions	218
8.2	A Simple Hash Example	222
8.3	The Secure Hash Algorithm	224
8.4	Birthday Attacks	229
8.5	Multicollisions	232
8.6	The Random Oracle Model	235
8.7	Using Hash Functions to Encrypt	238
8.8	Exercises	239
8.9	Computer Problems	242

9 Digital Signatures	244
9.1 RSA Signatures	245
9.2 The ElGamal Signature Scheme	246
9.3 Hashing and Signing	249
9.4 Birthday Attacks on Signatures	250
9.5 The Digital Signature Algorithm	251
9.6 Exercises	252
9.7 Computer Problems	255
10 Security Protocols	256
10.1 Intruders-in-the-Middle and Impostors	257
10.2 Key Distribution	259
10.3 Kerberos	266
10.4 Public Key Infrastructures (PKI)	270
10.5 X.509 Certificates	271
10.6 Pretty Good Privacy	277
10.7 SSL and TLS	280
10.8 Secure Electronic Transaction	283
10.9 Exercises	285
11 Digital Cash	287
11.1 Digital Cash	287
11.2 Exercises	294
12 Secret Sharing Schemes	296
12.1 Secret Splitting	296
12.2 Threshold Schemes	297
12.3 Exercises	303
12.4 Computer Problems	305
13 Games	307
13.1 Flipping Coins over the Telephone	307
13.2 Poker over the Telephone	309
13.3 Exercises	314
14 Zero-Knowledge Techniques	316
14.1 The Basic Setup	316
14.2 The Feige-Fiat-Shamir Identification Scheme	319
14.3 Exercises	321
15 Information Theory	325
15.1 Probability Review	326
15.2 Entropy	328
15.3 Huffman Codes	333

15.4	Perfect Secrecy	335
15.5	The Entropy of English	338
15.6	Exercises	343
16	Elliptic Curves	347
16.1	The Addition Law	347
16.2	Elliptic Curves Mod p	352
16.3	Factoring with Elliptic Curves	356
16.4	Elliptic Curves in Characteristic 2	360
16.5	Elliptic Curve Cryptosystems	363
16.6	Identity-Based Encryption	366
16.7	Exercises	370
16.8	Computer Problems	374
17	Lattice Methods	376
17.1	Lattices	376
17.2	Lattice Reduction	377
17.3	An Attack on RSA	382
17.4	NTRU	385
17.5	Exercises	390
18	Error Correcting Codes	392
18.1	Introduction	392
18.2	Error Correcting Codes	398
18.3	Bounds on General Codes	402
18.4	Linear Codes	408
18.5	Hamming Codes	416
18.6	Golay Codes	417
18.7	Cyclic Codes	426
18.8	BCH Codes	432
18.9	Reed-Solomon Codes	440
18.10	The McEliece Cryptosystem	442
18.11	Other Topics	444
18.12	Exercises	445
18.13	Computer Problems	449
19	Quantum Techniques in Cryptography	450
19.1	A Quantum Experiment	451
19.2	Quantum Key Distribution	454
19.3	Shor's Algorithm	456
19.4	Exercises	466

A Mathematica® Examples	467
A.1 Getting Started with Mathematica	467
A.2 Some Commands	469
A.3 Examples for Chapter 2	470
A.4 Examples for Chapter 3	477
A.5 Examples for Chapter 6	480
A.6 Examples for Chapter 8	487
A.7 Examples for Chapter 12	487
A.8 Examples for Chapter 13	488
A.9 Examples for Chapter 16	490
B Maple® Examples	495
B.1 Getting Started with Maple	495
B.2 Some Commands	496
B.3 Examples for Chapter 2	498
B.4 Examples for Chapter 3	505
B.5 Examples for Chapter 6	509
B.6 Examples for Chapter 8	517
B.7 Examples for Chapter 12	518
B.8 Examples for Chapter 13	519
B.9 Examples for Chapter 16	521
C MATLAB® Examples	527
C.1 Getting Started with MATLAB	528
C.2 Examples for Chapter 2	533
C.3 Examples for Chapter 3	544
C.4 Examples for Chapter 6	548
C.5 Examples for Chapter 8	553
C.6 Examples for Chapter 12	553
C.7 Examples for Chapter 13	554
C.8 Examples for Chapter 16	556
D Suggestions for Further Reading	564
Bibliography	565
Index	571