This is a Chapter from the **Handbook of Applied Cryptography**, by A. Menezes, P. van Oorschot, and S. Vanstone, CRC Press, 1996.

For further information, see www.cacr.math.uwaterloo.ca/hac

CRC Press has granted the following specific permissions for the electronic version of this book:

Permission is granted to retrieve, print and store a single copy of this chapter for personal use. This permission does not extend to binding multiple chapters of the book, photocopying or producing copies for other than personal use of the person creating the copy, or making electronic copies available for retrieval by others without prior permission in writing from CRC Press.

Except where over-ridden by the specific permission above, the standard copyright notice from CRC Press applies to this electronic version:

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

The consent of CRC Press does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press for such copying.

©1997 by CRC Press, Inc.

<b>Symbols</b> $ S $ (cardinality of a set $S$ ), 49 $\in$ (set member), 49	$\mathbb{Z}$ (the integers), 49 $\mathbb{Z}_n$ (integers modulo $n$ ), 68 $\mathbb{Z}_n^*$ (multiplicative group of $\mathbb{Z}_n$ ), 69
$\subseteq$ (subset), 49	$Q_n$ (quadratic residues modulo $n$ ), 70
c (proper subset), 49	$\overline{Q}_n$ (quadratic non-residues modulo $n$ ), 70
(set intersection), 49	$\mathbb{F}_q$ (finite field of order $q$ ), 81
U (set union), 49	$\mathbb{F}_q^*$ (multiplicative group of $\mathbb{F}_q$ ), 81
- (set difference), 49	R[x] (polynomial ring), 78
× (Cartesian product), 49	∨ (inclusive-OR), 213
Ø (empty set), 50	(AND) 212
O-notation (big-O), 58	$\wedge$ (AND), 213
Ω-notation (big-omega), 59	$\boxplus$ (addition mod $2^n$ ), 263
Θ-notation (big-theta), 59	$\exists$ (subtraction mod $2^n$ ), 270
o-notation (little-o), 59	$\odot$ (modified multiplication mod $2^n + 1$ ), 263
$\stackrel{\text{def}}{=}$ (by definition), 213	$\leftarrow$ (left rotation), 213
$L_q[\alpha,c]$ (subexponential notation), 60	$\hookrightarrow$ (right rotation), 213
$\leq_P$ (polytime reduction), 61	$A \rightarrow B$ (message transfer), 396
~ (asymptotic equivalence), 134	A
$\pi$ (mathematical constant pi), 49	
e (base of natural logarithms), 49	Abelian group, 75 Abstract Syntax Notation One (ASN 1) 660
$\sum$ (sum), 50	Abstract Syntax Notation One (ASN.1), 660
∏ (product), 50	Access control, 3
! (factorial), 50	Access control matrix, 387
[ ] (floor), 49	Access matrix model, 569
[ ] (ceiling), 49	Access structure, 526
$\phi$ (Euler phi function), 65, 286	monotone, 527
$\mu(n)$ (Möbius function), 154	Accredited Standards Committee (ASC), 648
lg (base 2 logarithm), 50	Active adversary, 15, 37
ln (natural logarithm), 50	Active attack, 41, 495
[a, b] (interval of integers), 49	Ad hoc security, 43
(divides relation), 63, 79	Adaptive chosen-ciphertext attack, 42
$\equiv$ (congruence relation), 67, 79	Adaptive chosen-message attack, 433
$\ll$ (much less than), 529	Adaptive chosen-plaintext attack, 41
$\gg$ (much greater than), 170	Addition chains, 621, 633
$\binom{n}{k}$ (binomial coefficient), 52	Adversary, 13, 495
$\left(\frac{a}{p}\right)$ (Legendre symbol), 72	active, 15
< > (inner product), 118	insider, 496
x   (length of a vector $x$ ), 118	one-time, 496
$a \leftarrow b$ (assignment operator), 66	permanent, 496
a  b (concatenation of strings $a,b$ ), 38	outsider, 496
$\{0,1\}^k$ (bitstrings of bitlength k), 447	passive, 15
$\{0,1\}^*$ (bitstrings of arbitrary bitlength), 447	Affine cipher, 239
$\mathbb{Q}$ (the rational numbers), 49	Algebraic normal form, 205
$\mathbb{R}$ (the real numbers), 49	Algorithm
	definition of, 57

deterministic, 62	local, 419
exponential-time, 59	meet-in-the-middle, 235
polynomial-time, 59	misplaced trust in server, 531
randomized, 62	non-interactive, 419
expected running time, 63	off-line, 419
running time, 58	on-line, 419
asymptotic, 58	passive, 41, 495
average-case, 58	pre-play, 397
worst-case, 58	reflection, 417, 530, 540
subexponential-time, 60	related-key, 226
Alphabet of definition, 11	remote, 419
Alternating step generator, 209–211, 220	replay, 42, 417
Anonymity, 3	time-memory tradeoff, 236
ANSI standards, 648–651, 660	truncated differentials, 271
ordering and acquiring, 656	universal forgery, 482
ANSI X9.17 pseudorandom bit generator, 173	Attacker, 13
Anti-palindromic keys of DES, 257	Attacker (alternate names), 495
Appended authenticator, 361	see also Adversary
Arbitrated signature scheme, 472–473	Attribute certificate, 561
Arithmetic	Audit trail, 549, 583
integer, see Multiple-precision integer arithmetic	Audit trail information, 545
modular, see Multiple-precision modular arith-	Authenticated key establishment, 492, 493
metic	Authenticated key exchange protocol
Arthur-Merlin games, 421	AKEP1/AKEP2, 499, 535, 541
ASN.1, see Abstract Syntax Notation One (ASN.1)	Authentication
Asymmetric cryptographic system, 544	
Asymptotic running time, 58	data origin, 4, 361
Asymptotic running time, 38 Atkin's primality test, 145	see also Data origin authentication entity, 4
	•
implementation report, 166	see also Entity authentication
Attack	explicit key, 492
active, 41, 495	key, 492
adaptive chosen-ciphertext, 42	message, 361
adaptive chosen-message, 433	mutual, 494
adaptive chosen-plaintext, 41	protocol, 493
chosen-ciphertext, 41, 226	transaction, 362
chosen-message, 433	unilateral, 494
chosen-plaintext, 41, 226	see also Entity authentication (and Identifica-
chosen-text, 417	tion)
ciphertext-only, 41, 225	Authentication code, 376, 382
dictionary, 42, 392	Authentication path, 557
differential cryptanalysis, 258	Authentication server, 491, 549
differential-linear, 271	Authentication tree, 466–468, 485, 556–559, 587
exhaustive key search, 233–234	Authority revocation list (ARL), 577
forced delay, 417	Authorization, 3
forward search, 42, 288, 420	Authorized subset, 527
impersonation, 42, 417	Auto-key cipher, 242
interleaving, 42, 417, 531, 540	Autocorrelation function, 180
intruder-in-the-middle, 530, 540	Autocorrelation test, 182
key-only, 432	Auxiliary-input zero-knowledge, 423
known-key, 42, 496, 534	Avalanche effect, 277
known-key triangle, 538	Average-case running time, 58
known-message, 432	Th.
known-plaintext, 41, 225	В
linear cryptanalysis, 258	Baby-step giant-step algorithm, 104-106, 128

BAN logic, 420, 534, 541	fair, 487
Bandwidth efficiency, 437	Blinded message, 475
Barrett reduction, 603–605, 631	Blinding function, 475
Base b representation, 592	based on RSA, 475
Basis, 80	Blob, 421
Bayes' theorem, 51	Block cipher, 223–282
BEAR block cipher, 282	3-WAY, 281
Beaufort cipher, 241	attacks on
Beller-Yacobi key transport	differential cryptanalysis, 258
2-pass, 514	differential-linear, 271
4-pass, 513	exhaustive key search, 233-234, 273
Berlekamp's Q-matrix algorithm, 124, 132	key clustering attack, 281
Berlekamp-Massey algorithm, 200–201	linear cryptanalysis, 258
next discrepancy, 200	meet-in-the-middle attack, 235
Bernoulli trial, 52	related-key attack, 226, 281
Biased, 172	time-memory tradeoff, 236, 273
Big-endian, 344	truncated differentials, 271, 280
Big-O notation, 58	BEAR, 282
Big-omega notation, 59	Blowfish, 281
Big-theta notation, 59	CAST, 281
Bijection, 7, 50	classical cipher, 237–250
Binary additive stream cipher, 194	definition of, 16, 224
keystream generator, 194	DES, 250–259
running key generator, 194	double DES, 235
Binary alphabet, 11	FEAL, 259–262
Binary Euclidean algorithm, 632	GOST, 282
Binary extended gcd algorithm, 608–610, 632	
	IDEA, 263–265
Binary gcd algorithm, 606–607, 632	iterated, 251
Binary operation, 75	Khafre, 271
Binary representation, 592	Khufu, 271
Binary tree, 557	LION, 282
balanced, 558	LOKI'91, 270
children, 557	Luby-Rackoff, 282
depth of, 558	Lucifer, 276
internal vertex, 557	modes of operation, 228–233, 272
leaf, 557	ANSI X3.106 standard, 649
parent, 557	ANSI X9.52 standard, 651
root vertex, 557	CBC with checksum (CBCC), 367
Binomial	cipher feedback mode (CFB), 231
coefficient, 52	cipher-block chaining mode (CBC), 230
distribution, 52	counter mode, 233
theorem, 52	electronic codebook mode (ECB), 228-
Biometrics, 387, 420	230
Birthday attack, 352, 369	FIPS 81 standard, 654
Birthday problem, 53	ISO 8372 standard, 645
Birthday surprise, 53	ISO/IEC 10116 standard, 647
Bit commitment, 421	output feedback mode (OFB), 232-233
Bitzer's hash function, 374	plaintext-ciphertext block chaining
Black-box, 329, 341, 369, 378	(PCBC), 368
Blakley's threshold scheme, 538	Randomized DES (RDES), 278
Blind signature scheme, 475, 487	RC2, 282
based on DSA, 487	RC5, 269–270
based on Nyberg-Rueppel, 487	round function, 251
Chaum, 475	SAFER, 266–269

sami waals kaya (af DES) 257	CDC MAC 252 254 267
semi-weak keys (of DES), 257	CBC-MAC, 353–354, 367
anti-palindromic keys (of DES), 257	ANSI X9.9 standard, 650
SHARK, 281	ANSI X9.19 standard, 650
SKIPJACK, 282, 584	FIPS 113 standard, 654
TEA, 282	ISO 8731-1 standard, 652
triple DES, 272	ISO 9807 standard, 652
WAKE, 282	ISO/IEC 9797 standard, 646
Block of a sequence, 180	Cellular automata stream cipher, 222
Blocklength, 224	Certificate
Blom's KDS bound, 505	ANSI X9.45 standard, 651
Blom's key pre-distribution system, 506, 536	ANSI X9.55 standard, 651
Blowfish block cipher, 281	ANSI X9.57 standard, 651
Blum integer, 74–75	caching, 576
Blum-Blum-Shub pseudorandom bit generator, 186–	chain, 572
187, 308	directory, 549
Blum-Goldwasser probabilistic public-key encryp-	pull model, 576
tion, 308–311	push model, 576
decryption algorithm, 309	forward, 575
encryption algorithm, 309	on-line, 576
key generation, 308	public-key, see Public-key certificate
security of, 310	reverse, 575
Blum-Micali pseudorandom generator, 189	revocation, 566, 576–577
Blundo's conference KDS bound, 529	RFC 1422, 655
Boolean function, 202	secret-key, see Secret-key certificate
algebraic normal form of, 205	symmetric-key, see Symmetric-key certificate
correlation immune, 207	X.509 standard, 660
nonlinear order of, 205	Certificate of primality, 166
<b>BPP</b> , 63	Certificate revocation list (CRL), 576–577
Break-backward protection, 496	Certification, 3
Brickell-McCurley identification protocol, 423	path, 572
Broadcast encryption, 528	policy, 576
Bucket hashing, 382	topology, 572
Burmester-Desmedt conference keying, 528	Certification authority (CA), 491, 548, 556, 559
Burst error, 363	Certificational attack, 236
Buist 61161, 363	Certificational weakness, 285
C	CFB, <i>see</i> Cipher feedback mode
CA, see Certification authority (CA)	CFB-64 MAC, 650
CA-certificate, 572	Challenge, 397, 409
Caesar cipher, 239	Challenge-response identification, 397–405, 420–
CALEA, 590	421
Capability (access control), 570	public-key, 403–405
Capstone chip, 589	ISO/IEC 9798-3, 404–405
Cardinality of a set, 49	modified Needham-Schroeder, 404
Carmichael number, 137	X.509, 404
Carry-save adder, 630	x.309, 404 symmetric-key, 400–403
Cartesian product, 49	The state of the s
-	ISO/IEC 9798-2, 401–402
Cascade cipher, 234, 237	SKID2, 402
Cascade generator	SKID3, 402
<i>m</i> -sequence, 221	Channel, 13
p-cycle, 220	physically secure, 13
Cascading hash functions, 334	secure, 13
CAST block cipher, 281	secured, 13
patent, 659	unsecured, 13
CBC, see Cipher-block chaining mode	Characteristic of a field, 77

Chaum's blind signature protocol, 475	Kasiski's method, 248
Chaum-van Antwerpen undeniable signature sch-	measure of roughness, 249
eme, 476–478	polyalphabetic substitution cipher, see Polyal-
disavowal protocol, 477	phabetic substitution cipher
key generation, 476	-
* <del>*</del>	substitution cipher, see Substitution cipher
security of, 478	transposition cipher, see Transposition cipher
signature generation, 476	Classical modular multiplication, 600
Chebyshev's inequality, 52	Classical occupancy problem, 53
Checksum, 362, 367–368	Claw-resistant (claw-free), 376, 468
Chi-square ( $\chi^2$ ) distribution, 177–179	Clipper chip, 584, 589
degrees of freedom, 177	key escrow, 584
mean of, 177	law enforcement access field (LEAF), 584
variance of, 177	Clipper key escrow, 654
Chinese remainder theorem (CRT), 68	Clock-controlled generator, 209–212
Garner's algorithm, 612–613	<b>co-NP</b> , 60
Gauss's algorithm, 68	Codebook, 240
Chipcard, 387, 424	Codomain of a function, 6, 50
Chor-Rivest public-key encryption, 302–306, 318	Collision, 321
attacks on, 318	pseudo-collision, 371
decryption algorithm, 303	Collision resistance, 324, 325
encryption algorithm, 303	Collision resistant hash function (CRHF), 325
key generation, 303	Combining function, 205
recommended parameter sizes, 305	Common modulus attack on RSA, 289
security of, 305	Commutative ring, 77
Chosen-ciphertext attack, 41, 226, 285	Complementation property of DES, 256–257
adaptive, 285	Complete function, 277
indifferent, 285	Complexity classes, 59–62
Chosen-message attack, 433	<b>BPP</b> , 63
directed, 482	co-NP, 60
generic, 482	<b>NP</b> , 60
Chosen-plaintext attack, 41, 226	NP-complete, 61
Cipher, 12	NP-hard, 62
see also Encryption	NPC, 61
Cipher-block chaining mode (CBC), 230	<b>P</b> , 60
integrity of IV in, 230	<b>RP</b> , 63
use in public-key encryption, 285	<b>ZPP</b> , 63
Cipher feedback mode (CFB), 231	Complexity measure
as a stream cipher, 233	2-adic span, 218
ISO variant of, 231	linear complexity, 198–201
Cipher machine, 242–245	maximum order complexity, 217
	Turing-Kolmogorov-Chaitin complexity, 217
Jefferson cylinder, 243	Ziv-Lempel complexity, 217
rotor-based machine, 243–245, 276	
Enigma, 245	Complexity of attacks on a block cipher, 225–227
Hagelin M-209, 245	active complexity, 226
Hebern, 244	attack complexity, 226
Wheatstone disc, 274	data complexity, 226
Ciphertext, 11	passive complexity, 226
Ciphertext-only attack, 41, 225	processing complexity, 226
Ciphertext space, 11	storage complexity, 226
Claimant, 385, 386	Complexity theory, 57–63
Classical cipher, 237–250, 273–276	Complexity-theoretic security, 43
cipher machines, see Cipher machine	Compliant, 532
cryptanalysis, 245–250, 275–276	Composite integer, 64
index of coincidence 248	Composition of functions 19

Computation-resistance (MAC), 325	Micali-Schnorr generator, 186
Computational problems	modified-Rabin generator, 190
computationally equivalent, 88	RSA generator, 185–186
polytime reduction, 88	Cryptography
Computational security, 43, 226	definition of, 4
Computational zero-knowledge protocol, 407	goals of, 4
Computationally equivalent decision problems, 61	CRYPTOKI, 656
COMSET, 421, 536	Cryptology, 15
Conditional entropy, 56	Cryptoperiod of a key, 553
Conditional probability, 51	Cryptosystem, 15
Conditional transinformation, 57	Cut-and-choose protocol, 410, 421
Conference keying, 528–529, 540	Cycle of a periodic sequence, 180
Blundo's conference KDS bound, 529	Cyclic group, 69, 76
Burmester-Desmedt, 528	generator of, 76
definition of, 528	Cyclic redundancy code (CRC), 363
Confidentiality, 3, 4, 12	Cyclic register, 220
Confirmation, 3	Cycling attacks on RSA, 289, 313
Confounder, 418	.,
Confusion, 20	D
Congruences	Data Authentication Algorithm (DAA), 654
integers, 67	Data Encryption Standard, see DES block cipher
polynomials, 79	Data integrity, 3, 4, 33, 359–368, 383
Conjugate gradient method, 129	Data key, 552
Connection polynomial of an LFSR, 196, 204	Data origin authentication, 3, 4, 25, 359–368, 491
known versus secret, 204	Davies-Meyer hash function, 341
sparse versus dense, 205	de Bruijn FSR, 203
Constrained linear equations problem, 423	de Bruijn sequence, 203
Continued fraction factoring algorithm, 126	De-skewing, 172
Continuous random variable, 176	DEA, 649
Control vector, 569	Decimated subsequence, 211
patent, 639, 658	Decision problems, 60
Conventional encryption, 15	computationally equivalent, 61
Coprime, 64	polytime reduction, 61
Correcting-block chaining attack, 373	Decryption, 11
Correlated, 172	Decryption exponent for RSA, 286
Correlation attack, 206, 218	Decryption function, 11
Correlation immunity, 207, 218	DECT, 586
Counter mode, 233	Degrees of freedom, 177
CRC-based MAC, 359	Delay element
Credential, 501	of an FSR, 202
CRHF, see Collision resistant hash function	of an LFSR, 195
Cross-certificate (CA-certificate), 572	Delayed-carry adder, 630
Cross-certificate pair, 573	Density of a knapsack set, 120
CRT, see Chinese remainder theorem	Derivative of a polynomial, 123
Cryptanalysis, 15	DES block cipher, 250–259, 276–278
Cryptanalyst, 15	ANSI X3.92 standard, 649
Cryptographic check value, 363	attacks on
Cryptographic primitives, 4	differential cryptanalysis, 258–259
taxonomy of, 5	exhaustive key search, 233–234, 272
Cryptographically secure pseudorandom bit gener-	linear cryptanalysis, 258–259
ator (CSPRBG), 185–187	complementation property, 256–257
Blum-Blum-Shub generator, 186–187	decryption algorithm, 255
Blum-Micali generator, 189	DESX, 273
definition of, 171	double DES, see Double DES

encryption algorithm, 253	Disavowal protocol, 477
expansion permutation, 252	Discrete Fourier Transform (DFT), 631
FIPS 46 standard, 654	Discrete logarithms, 103-113
initial permutation (IP), 252, 277	baby-step giant-step algorithm, 104-106
key schedule	composite moduli, 114
decryption, 256	exhaustive search, 104
encryption, 255	for class groups, 130
modes of operation, see Block cipher, modes	for elliptic curves, 130
of operation	for hyperelliptic curves, 130
patent, 636	function field sieve, 129
permuted choices (PC1, PC2), 252	generalized problem, 103
properties and strengths, 256–259	heuristic running time, 129
round, 252	in subgroups of $\mathbb{Z}_p^*$ , 113
S-box, 252	index-calculus algorithms, 109–112
semi-weak key, 257	lambda method, 128
anti-fixed point of, 257	number field sieve, 128
test vectors, 256	Pohlig-Hellman algorithm, 107–109
triple-DES, 273	Pollard's rho algorithm, 106–107
weak key, 257	problem definition, 103
fixed point of, 257	rigorously analyzed algorithms, 129
Designated confirmer signature, 487	security of individual bits, 116
Deterministic, 306	Divisible electronic coin, 487
Deterministic algorithm, 62	Division
Dickson polynomial, 314	of integers, 63
Dickson scheme, 314	of polynomials, 79
Dictionary attack, 42	Division algorithm
Difference of sets, 49	for integers, 64
Differential chaining attack, 375	for polynomials, 78
Differential cryptanalysis	Dixon's algorithm, 95, 127
of block ciphers, 258, 271, 278–280	DNA computer, 130
Differential-linear cryptanalysis, 271	Domain of a function, 6, 50
Diffie-Hellman key agreement, 515–520, 522–524	Double DES, 235
ANSI X9.42 standard, 651	Double spending, 487
composite modulus, 537	Double-length MDC, 339
patent, 637	DSA, see Digital Signature Algorithm
Diffie-Hellman problem, 113–114	Dynamic key establishment, 491
composite moduli, 114, 131	Dynamic secret sharing scheme, 527
generalized, 113	_
Diffie-Lamport one-time signature scheme, 485	${f E}$
Diffusion, 20	E-D-E triple encryption, 235, 272
Digital envelope, 550	E-E-E triple encryption, 272
Digital fingerprint, 321	Eavesdropper, 13, 495
Digital signature, see Signature	ECA, see Elliptic curve factoring algorithm
Digital Signature Algorithm (DSA), 452–454, 483	ECB, see Electronic codebook mode
ANSI X9.30-1 standard, 651	Effective key size, 224
FIPS 186 standard, 655	Electronic cash
key generation, 452	divisible, 487
patent, 640, 658	untraceable, 487
security of, 453	Electronic codebook mode (ECB), 228–230
signature generation, 452	ElGamal key agreement, 517
signature verification, 453	ElGamal public-key encryption, 294-298
use and throw coupons, 483	generalized
Dimension of a vector space, 80	decryption algorithm, 297
Dirichlet theorem, 135	encryption algorithm, 297

key generation, 297	FIPS 185, 654
in $\mathbb{Z}_p^*$	ESIGN signature scheme, 473–474, 486
decryption algorithm, 295	key generation, 473
encryption algorithm, 295	patent, 638, 658
key generation, 294	security of, 474
recommended parameter sizes, 296	signature generation, 473
security of, 296	signature verification, 473
ElGamal signature scheme, 454–459, 484	Euclidean algorithm
generalized	for integers, 66
key generation, 458	for polynomials, 81–83
signature generation, 458	Euler liar, 138
signature verification, 458	Euler phi function $(\phi)$ , 65
in $\mathbb{Z}_p^*$	Euler pseudoprime, 138
key generation, 454	Euler witness, 137
security of, 455–456	Euler's criterion, 137
signature generation, 454	Euler's theorem, 69
signature verification, 454	Exclusive-or (XOR), 20
signature verification, 618	Exhaustive key search, 14, 233–234, 272
variants of, 457	Existential forgery, 30, 326, 432
Elliptic curve	exp (exponential function), 50
discrete logarithm problem, 130	Expected running time, 63
	Expected running time, 63 Explicit authentication, 492
ElGamal public-key encryption, 297	
in public-key cryptography, 316	Exponent array, 617
patents, 659	Exponent recoding, see Exponentiation
RSA analogue, 315	Exponential-time algorithm, 59
supersingular curve, 130, 316	Exponentiation, 613–629, 633–634
Elliptic curve factoring algorithm (ECA), 94, 125	addition chains, 621
implementation reports, 126	exponent recoding, 627–629
Elliptic curve primality proving algorithm, 145	signed-digit representation, 627–628
Encrypted key exchange (EKE), 538	string-replacement representation, 628–
Encryption, 11	629
see also Block cipher	fixed-base comb method, 625–627
see also Public-key encryption	fixed-base Euclidean method, 624–625
see also Stream cipher	fixed-base windowing method, 623–624
Encryption exponent for RSA, 286	left-to-right binary method, 615
Encryption function, 11	left-to-right $k$ -ary method, 615
Encryption scheme, 12	modified left-to-right $k$ -ary method, 616
breakable, 14	Montgomery method, 619–620
Enemy, 13, 495	repeated square-and-multiply algorithm, 71,
Enigma, 245, 276	84
Entity, 13	right-to-left binary method, 614
Entity authentication, 3, 386, 491	simultaneous multiple, 617–618
ANSI X9.26 standard, 651	sliding-window method, 616
FIPS 196 standard, 655	vector-addition chains, 622-623
ISO 11131 standard, 652	Extendable secret sharing scheme, 526
ISO/IEC 9798 standard, 401-402, 404-405, 421,	Extended Euclidean algorithm
647	for integers, 67
see also Identification	for polynomials, 82
Entropy, 56–57, 246	Extended Riemann Hypothesis (ERH), 165
Ephemeral secret, 494	Extension field, 77
Equivalence class, 68, 79	Extractor, 406
Equivocation, 56	
Error-correcting code, 298, 363, 506	$\mathbf{F}$
Escrowed Encryption Standard (EES)	Factor base, 94, 109

<sup>©1997</sup> by CRC Press, Inc. — See accompanying notice at front of chapter.

Factoring integers, see Integer factorization	Field, 77
Factoring polynomials, see Polynomial factoriza-	characteristic of, 77
tion	definition of, 77
Fail-stop signature scheme, 478–481, 488	extension field of, 77
Heijst-Pedersen, 478–481	finite, see Finite field
Fair blind signature scheme, 487	subfield of, 77
Fair cryptosystems, 640–641, 658	Filtering function, 208
for Diffie-Hellman key agreement, 641	Finite field, 80–85
patent, 640	definition of, 80
FEAL block cipher, 259–262, 278–279	order of, 80
attacks on, 278–279	polynomial basis, 83
FEAL decryption algorithm, 261	FIPS, 654–655, 661
FEAL-8 encryption algorithm, 261	ordering and acquiring, 656
FEAL-8 key schedule, 261	FIPS 186 pseudorandom bit generator, 174–175
FEAL-N, 262	FISH stream cipher, 222
FEAL-NX, 262	Fixed-point chaining attack, 374
patent, 639	Floyd's cycle-finding algorithm, 91, 125
test vectors, 262	Forced delay attack, 417
Feedback shift register (FSR), 195-203	Formal methods, 534, 541
de Bruijn, 203	Forward certificate, 575
definition of, 202	Forward error correction, 363
delay element of, 202	Forward search attack, 34, 42, 288, 420
feedback bit of, 202	Fractionation, 276
feedback function of, 202	Frequency distribution
Feedback with carry shift register (FCSR), 217-	of English digrams, 247
218, 222	of single English characters, 247
initial state of, 202	Frequency test, 181
linear feedback shift register, see Linear feed-	Fresh key, 494
back shift register (LFSR)	Function, 6–10, 50
non-singular, 203	bijection, 7
nonlinear feedback shift register, 202	composition of, 19
output sequence of, 202	definition of, 6
stage of, 202	injective, 46
Feedback with carry shift register (FCSR), 217–218,	inverse, 7
222	involution, 10
Feige-Fiat-Shamir identification protocol, 410–412,	one-to-one, 7
422	one-way, 8
Feige-Fiat-Shamir signature scheme, 447–449, 483	onto, 7
identity-based modification, 449	permutation, 10
key generation, 447	surjective, 46
security of, 448	trapdoor one-way, 9
signature generation, 448	Function field sieve, 129
signature verification, 448	Functional diagram, 6
Feistel cipher, 251, 276	Functional graph, 54
Fermat liar, 136	component size, 55
Fermat number, 143, 166	cycle length, 55
Fermat witness, 136	predecessors size, 55
Fermat's primality test, 136	rho-length, 55
Fermat's theorem, 69	tail length, 55
Fiat-Shamir identification protocol	tree size, 55
basic version, 408	Functionally trusted third party, 39
patent, 638, 658	
Fiat-Shamir signature scheme, 483	G
patent, 638, 658	Gap of a sequence, 180

Garner's algorithm, 612-613	of units, 77
Gauss's algorithm, 68	order of, 75
Gaussian integer method, 128	subgroup of, 76
gcd, see Greatest common divisor	Group signature, 488
Geffe generator, 206	GSM, 586
General-purpose factoring algorithm, 90	GSS-API, 655, 661
Generator	Günther's implicitly-certified public key, 521
of a cyclic group, 76, 160	Günther's key agreement, 522
algorithm for finding, 163	
of $\mathbb{F}_q^*$ , 81	$\mathbf{H}$
of $\mathbb{F}_{2m}^*$ , 163	Hagelin M-209, 245, 276
of $\mathbb{Z}_n^*$ , 69	Hamming weight, 105
of $\mathbb{Z}_p^*$ , 164	Handwritten signature, 23
algorithm for selecting, 164	Hard predicate, 115
Generator matrix, 506	Hash function, 33, 321–383
Girault self-certified public key, 522	alternate terminology, 325, 371
GMR one-time signature scheme, 468–471, 486	applications, 321–322, 330–331
authentication tree, 470	attacks, 368–375
key generation, 469	birthday, 369-371
security of, 470	chaining, 373–375
signature generation, 469	Pseudo-collisions, 371–373
signature verification, 469	based on block ciphers, 338-343
GOAL stream cipher, 219	Abreast Davies-Meyer, 380
Goldwasser-Kilian primality test, 166	Davies-Meyer, 341
Goldwasser-Micali probabilistic public-key encryp-	Matyas-Meyer-Oseas, 341
tion, 307–308	MDC-2, 342
decryption algorithm, 307	MDC-4, 343
encryption algorithm, 307	Merkle's DES-based hash, 338, 339, 378
key generation, 307	Miyaguchi-Preneel, 341
security of, 308	N-Hash, 380
Golomb's randomness postulates, 180	Tandem Davies-Meyer, 380
Goppa code, 299, 317	based on modular arithmetic, 351–352
Gordon's algorithm for strong prime generation, 150	MASH-1, 352
GOST block cipher, 282	MASH-2, 352
GQ identification protocol, 412–414, 422	cascading, 334
patent, 639, 658	collision resistant (CRHF), 325
GQ signature scheme, 450–451	customized, 343–351
	HAVAL, 379
key generation, 450	MD2, 380
message recovery variant, 451	MD4, 346
patent, 639, 658	
security of, 451	MD5, 347 RIPEMD, 380
signature generation, 450	RIPEMD-128, 339, 380
signature verification, 450	
Grandmaster postal-chess problem, 418	RIPEMD-160, 339, 350
Greatest common divisor	Secure Hash Algorithm (SHA-1), 348
binary extended gcd algorithm, 608–610, 632	Snefru, 380
binary gcd algorithm, 606–607, 632	definition of, 322
Euclidean algorithm, 66	ideal security, 336
Lehmer's gcd algorithm, 607–608, 632	initialization value (IV), 335
of integers, 64	MD-strengthening, see MD-strengthening
of polynomials, 81	Merkle's meta-method, 333
Group, 75–76	one-way (OWHF), 325
cyclic, 76	padding, 334–335
definition of, 75	properties of

2nd-preimage resistance, 323	forced delay, 417
collision resistance, 324	impersonation, 417
compression, 322	interleaving, 417
ease of computation, 322	local, 419
local one-wayness, 331	non-interactive, 419
near-collision resistance, 331	off-line, 419
non-correlation, 331	pre-play, 397, 398
partial-preimage resistance, 331	reflection, 417
preimage resistance, 323	remote, 419
strong collision resistance, 324	replay, 417
weak collision resistance, 324	challenge-response, see Challenge-response
r-collision resistant, 424	identification
strong one-way, 325	mutual, 387
universal classes of, 376	passwords, see Passwords (weak
universal one-way, 377	authentication)
weak one-way, 325	questionnaire-based, 420
Hash-code, 321	relation to signatures, 388
Hash-result, 321	unilateral, 387
Hash-value, 33, 321	zero-knowledge, see Zero-knowledge identifi-
HAVAL hash function, 379	cation
Heijst-Pedersen fail-stop signature scheme, 478–481	see also Entity authentication
key generation, 478	Identification Friend or Foe (IFF) system, 421
proof-of-forgery algorithm, 481	Identity verification, 385
signature generation, 479	Identity-based key establishment, 493
signature verification, 479	Identity-based system, 538, 561-562, 587
Hellman-Merkle patent, 637, 658	IDUP, 661
Heuristic security, 43, 533	IEEE P1363 standard, 660
High-order digit, 593	IETF, 655
Hill cipher, 240, 274	Image of a function, 6, 50
Historical work factor, 44	Impersonation, 27, 42, 386, 417
HMAC, 355	Impersonator, 495
Homomorphic property of RSA, 289	Implicit key authentication, see Key authentication
Homophonic substitution cipher, 17, 240	Implicitly-certified public key, 520–522, 562–563,
Hybrid protocol, 512	588
Hyperelliptic curve	Diffie-Hellman using, 522–524
discrete logarithm problem, 130	identity-based, 563
ElGamal public-key encryption, 297	of Girault, 522
Hypothesis testing, 179–180	of Günther, 521
-	self-certified, 563
l	Imprint, 321
IC card, 387	Improved PES (IPES), 279
IDEA block cipher, 263–265, 279–280	In-line trusted third party, 547
attacks on, 279–280	Incremental hashing, 378
decryption algorithm, 264	Independent events, 51
encryption algorithm, 264	Index of coincidence, 248, 275
key schedule, 264	Index-calculus algorithm, 109–112, 128
patent, 640, 658	Gaussian integer method, 128
test vectors, 265	in $\mathbb{F}_{2^m}$ , 111
weak keys, 279	implementation reports, 128
Ideal secret sharing scheme, 526, 527	in $\mathbb{Z}_p$ , 110
Identification, 3, 24–25, 385–424	implementation reports, 128
applications of, 387	linear sieve, 128
attacks on, 417–420, 424	residue list sieve, 128
chosen-text, 417	Information dispersal algorithm (IDA), 539

Information rate, 527	Involution, 10
Information security, 2	Irreducible polynomial, 78, 154–160
objectives of, 3	algorithm for generating, 156
Information security service, 14	algorithm for testing, 155
breaking of, 15	number of, 155
Information theory, 56–57	primitive polynomial, see Primitive
Initial state	polynomial
of an FSR, 202	trinomials, 157
of an LFSR, 196	ISO standards, see ISO/IEC standards
Injective function, 46, 50	ISO/IEC 9796, 442-444, 482-483
Inner product, 118	ISO/IEC standards, 645-648, 651-653, 660-661
Input size, 58	committee draft (CD), 645
Insider, 496	draft international standard (DIS), 645
one-time, 496	ordering and acquiring, 656
permanent, 496	working draft (WD), 645
Integer, 49	Isomorphic, 81, 104
multiple-precision, 593	Iterated block cipher, 251
negative	ITU, 653
signed-magnitude representation, 593	,
two's complement representation, 594	J
single-precision, 593	Jacobi sum primality test, 144, 166
Integer arithmetic, see Multiple-precision integer	Jacobi symbol, 73
arithmetic	computing, 73
Integer factorization, 89–98	Jefferson cylinder, 243, 274
continued fraction algorithm, 126	Joint entropy, 56
Dixon's algorithm, 95, 127	JTC1, 645
elliptic curve algorithm, 94	
general number field sieve, 98	K
general-purpose algorithms, 90	Karatsuba-Ofman multiplication, 630
heuristic running times, 127	Kasiski's method, 248, 275
multiple polynomial quadratic sieve, 97	KDC, see Key distribution center (KDC)
Pollard's $p-1$ algorithm, 92–93	Kerberos authentication protocol, 401, 501-502,
Pollard's rho algorithm, 91–92	535–536
problem definition, 89	RFC 1510, 656
quadratic sieve algorithm, 95–97	Kerckhoffs' assumption, 225
random square methods, 94–98	Kerckhoffs' desiderata, 14
special number field sieve, 98	Key, 11
special-purpose algorithms, 90	archival, 580
trial division, 90–91	backup, 580
Integers modulo $n$ , 67–71	cryptoperiod of, 553
Integrity check value (ICV), 363	data, 552
Interactive proof system, 406	de-registration, 580
Arthur-Merlin games, 421	derived, 568
completeness, 406	destruction, 580
soundness, 406	fresh, 494
Interleaving attack, 42, 417, 531, 540	generator, 549
Interloper, 13	installation, 579
Internal vertex, 557	key-encrypting, 552
Internet security standards, 655–656, 661	key-transport, 552
Intersection of sets, 49	layering, 551–553
Intruder, 13, 495	long-term, 553
Intruder-in-the-middle attack, 530, 540	master, 551
Inverse function, 7	notarization, 568
Inversion attack on stream ciphers, 219	offsetting, 568
cipion, 217	private, 27, 544

public, 27, 544 public-key vs. symmetric-key, 31–32, 551 recovery, 580 registration, 579 revocation, 566, 580 secret, 544 separation, 567 short-term, 553 symmetric, 544 terminal, 552 update, 580 Key access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536–538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTLAO, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key control, 494 Key control, 494 Key distribution confidential keys, 551–555 key layering, 551–553 key distribution center, 555–559 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicity-certified, 52–63 Key distribution problem, 16, 546 Key distribution system (KDS), 505 security against coalitions, 505 Key excrow, 584–586 agent, 550, 584 Clipper, 585 Cleved tham-Schroeder public-key, 588 Cey tanablishment, 489–54	11: 07 544	g (; 520
recovery, 580 registration, 579 revocation, 566, 580 secret, 544 separation, 567 short-term, 553 symmetric, 544 terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536–538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTLAO, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 530, 584 Clipper, 584 Key escrow, 584–586 segent, 530, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 intruder-in-the-middle, 530  compliant, 23, 490 identity-based, 493 key agreement, see Key agreement key transport see Key agreement, 491 identity-based, 493 key agreement, 493 operational, 352 resilient, 532 smiplified classification, 491 Key slife cycle, 577–581 key slife cycle, 577–581 key slife cycle, 577–581 key states, 580 Key authentication, 492 Key authentication, 492 Key control, 494 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 559–561 authentication trees, 556–559 certificates, 559–561 identity-based, 493 key agreement, see Key gareement key tire variously, 500 ANSI N9, 28 standard, 650 ANSI N9, 28 standard, 651 centralized, 546 key attrablation of, 53, 544 SNSI N9, 28 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO		
registration, 579 revocation, 566, 580 secret, 544 separation, 567 short-term, 553 symmetric, 544 terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 505-506, 515-524, 536-538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517-519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key confirmation, 492 Key control, 494 Key derivation, 490 Key distribution confidential keys, 551-555 key layering, 551-553 key translation center, 553-556 authentication trees, 556-559 certificates, 559-561 identity-based, 493 key agreement, see Key gargeement key transport, see Key transport message-independent, 493 operational, 532 resilient, 532 resilient, 532 resilient, 532 resilient, 532 simplified classification, 491 Key states, 580 Key management, 36-38, 543-590 ANSI X9, 28 standard, 650 ANSI X9, 28 standard, 651 controlling key usage, 567-570 definition of, 35, 544 ISO 8732 standard, 652 ISO 1106 standard, 652 ISO 1156 standard, 652 ISO 1156 standard, 654 Key distribution confidential keys, 551-555 public keys, 555-566 authentication trees, 556-559 certificates, 559-561 identity-based, 561-562 implicity-certified, 562-563 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584-586 agent, 550, 584 Clipper, 584 Key establishment, 489-541 analysis of, 530-534, 540-541 attacks on interleaving, 531 intruder-in-the-middle, 530  richer latusition of, 490 key transport, 491 Key ifric cycle, 577-581 key transport, 56 Ke		
revocation, 566, 580 secret, 544 separation, 567 short-term, 553 symmetric, 544 terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536– 538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/Ao, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key largering, 551–553 key translation center (KDC), 491, 500, 547 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–584 quent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 intruder-in-the-middle, 530		•
secret, 544 separation, 567 short-term, 553 symmetric, 544 terminal, 552 update, 580 Wey access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536– 538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key confirmation, 492 Key confirmation, 492 Key confoindential keys, 551–555 key layering, 551–555 key layering, 551–555 key layering, 551–555 key layering, 555–566 authentication trees, 553–554 symmetric-key certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution pattern, 36 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530  key agreement, 491 key transport, see Key transport message-independent, 493 operational, 532 resiliend, 132 coperational, 532 resiliend, 132 coperational, 532 resiliend, 132 coperational, 532 resiliend, 132 coperational, 532 simplified classification, 491 Key life cycle, 577–581 Key atmandard, 650 ANSI X9,17 standard, 650 ANSI X9,17 standard, 650 ANSI X9,28 standard, 651 ANSI X9,28 standard, 651 Controlling key usage, 567–570 definition of, 35,0 44 ISO 8732 standard, 652 ISO 1166 standard, 652 ISO 11568 standard, 652 ISO 1156		
separation, 567 short-term, 553 symmetric, 544 terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 508–506, 515–524, 536– 538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication trees, 555–554 key clustering attack on block ciphers, 281 Key confirmation, 492 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–555 key layering, 551–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certificate, 562–563 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution pattern, 536 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution pattern, 536 Key distribution pa		•
short-term, 553 symmetric, 544 terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536– 538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key cultstering attack on block ciphers, 281 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicity-certified, 562–563 Key distribution pattern, 536 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key excrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530		
symmetric, 544 terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536 538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/Ao, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–555 key layering, 551–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicity-certified, 562–563 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530  Vey Rose of the cycle, 577–581 Key life cycle, 577–581 Key life cycle, 577–581 Key states, 580 Key management, 36–38, 543–590 ANSI X9.24 standard, 650 ANSI X9.24 standard, 651 controlling key usage, 567–570 definition of, 35, 544 Sibo Manal Andre, 651 ANSI X9.24 standard, 651 Controlling key usage, 567–570 definition of, 35, 544 Sibo Manal Andre, 652 Liso 11568 standard, 652 ISO 11166 standard, 652 ISO 11166 standard, 652 ISO 11166 standard, 652 ISO 11568 standard, 65		
terminal, 552 update, 580 variant, 568 Key access server, 549 Key agreement, 34, 35, 505–506, 515–524, 536– 538 Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key confirmation, 492 Key confirmation, 492 Key control, 494 Key derivation, 490 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system, KDS bound, 505 security against coalitions, 505 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530  resilient, 532 simplified classification, 491 key kife cycle, 577–581 key states, 580 Key key states, 580 Key management, 36–38, 543–590 ANSI X9.24 standard, 650 ANSI X9.22 standard, 651 controlling key usage, 567–570 definition of, 35, 544 ISO 8732 standard, 652 ISO 11166 standard, 652 ISO 11166 standard, 652 ISO 11166 standard, 653 ISO/IEC 11770 standard, 652 ISO 1166 standard, 653 ISO/IEC 11770 standard, 652 ISO 1166 standard, 653 ISO/IEC 11770 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 653 ISO/IEC 11770 standard, 652 ISO 1166 standard, 653 ISO/IEC 11770 standard, 652 ISO 1166		
update, 580  Key ariant, 568  Key access server, 549  Key agreement, 34, 35, 505–506, 515–524, 536–538  Blom's key pre-distribution system, 506     definition of, 490     Diffie-Hellman, 516     ElGamal, 517     encrypted key exchange (EKE), 538     Günther, 522     MTI/Ao, 517–519     relation to key transport, 491     Station-to-station (STS), 519     Key authentication, 492     Key confirmation, 492     Key distribution system, 506     authentication 491  Key derivation, 490, 498     Key distribution center, 553–554     symmetric-key certificates, 559–561     identity-based, 561–562     implicitly-certified, 562–563     Key distribution pattern, 536     Key distribution problem, 16, 546     Key distribution system (KDS), 505     Blom's KDS bound, 505     security against coalitions, 505     Key establishment, 489–541     analysis of, 530–534, 540–541     attacks on interleaving, 531     intruder-in-the-middle, 530      interleaving, 531     intruder-in-the-middle, 530      Key instandard, 650     ANSI X9.24 standard, 651     centralized, 546     controlling key usage, 567–570     definition of, 35, 544     Manst X9.24 standard, 651     centralized, 546     controlling key usage, 567–570     definition of, 35, 544     ISO 8722 standard, 652     ISO 11062-7 standard, 652     ISO 11062-7 standard, 652     ISO 11064 standard, 652     ISO 11068 standard, 652     ISO 11166 standard, 653     ISO/IEC 11770 standard, 652     ISO 11064 standard, 652     ISO 11166 standard, 652     ISO 11068 standard, 653     ISO/IEC 11770 standard, 652     ISO 11064 s		
variant, 568  Key access server, 549  Key agreement, 34, 35, 505–506, 515–524, 536–538  Blom's key pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key distribution of, 490 Key confirmation, 492 Key control, 494 Key confirmation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution pattern, 536 Key distri		
Key access server, 549         key agreement, 34, 35, 505–506, 515–524, 536–538         Key agreement, 34, 35, 505–506, 515–524, 536–538         Key management, 36–38, 543–590           Blom's key pre-distribution system, 506 definition of, 490         ANSI X9.17 standard, 650           Diffie-Hellman, 516         ANSI X9.24 standard, 651           ElGamal, 517         encrypted key exchange (EKE), 538         controlling key usage, 567–570           Günther, 522         definition of, 35, 544           MTI/A0, 517–519         ISO 10202-7 standard, 652           relation to key transport, 491         ISO 10202-7 standard, 652           Station-to-station (STS), 519         ISO 1166 standard, 652           Key cutsering attack on block ciphers, 281         Key control, 492           Key control, 494         key distribution, see Key distribution confidential keys, 551–555         key distribution confidential keys, 551–555         key distribution confidential keys, 551–555         key life cycle, 577–581         key management facility, 549           Key distribution creter (KDC), 491, 500, 547         Key management facility, 549         Key management facility, 549           Key distribution or, 555–566         Key management facility, 549         Key management facility, 549           Key distribution or, 555–556         Key management facility, 549         Key management facility, 549           Key management facility, 549         Key manage	-	
Key agreement, 34, 35, 505–506, 515–524, 536–538 Blom's kDy pre-distribution system, 506 definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system, 506 ANSI X9.24 standard, 650 ANSI X9.28 standard, 651 ANSI X9.28 standard, 651 centralized, 546 controlling key usage, 567–570 definition of, 35, 544 ISO 10202-7 standard, 652 ISO 11166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 653 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 652 ISO 1166 standard, 653 ISO 1166 standard, 652		
Blom's key pre-distribution system, 506 definition of, 490  Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key confirmation, 492 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–555 key layering, 551–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicity-certified, 562–563 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530  ANSI X9.24 standard, 651 ANSI X9.24 standard, 651 centralized, 546 controlling key usage, 567–570 definition of, 35, 544 ISO 8732 standard, 652 ISO 11568 standard, 652	•	
Blom's key pre-distribution system, 506   definition of, 490   ANSI X9.28 standard, 651   ANSI X9.28 standard, 651   ANSI X9.28 standard, 651   ElGamal, 516   Centralized, 546   Centralized, 547   Centralized, 548   Centralized, 548   Centralized, 548   Centralized, 546   Centralized, 547   Centralized, 548   Centralized, 546   Centralized, 547   Centralized, 546   Centralized, 546   Centralized, 547   Centralized, 547   Centralized, 547   Centralized, 548   Centralized, 546   Centralized, 548   Centralized, 547   Centralized, 548   Centralized, 548   Centralized, 548   Centralized, 548   Cent		
definition of, 490 Diffie-Hellman, 516 ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key clustering attack on block ciphers, 281 Key confirmation, 492 Key controll, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–555 key layering, 551–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 anteroaccide and controlling key usage, 567–570 definition of, 35, 544 ANSI X9.28 standard, 651 centralized, 546 controlling key usage, 566–570 definition of, 35, 544 ISO 10202-7 standard, 652 ISO 11568 standard, 652 ISO 1166 standard, 6		
Diffie-Hellman, 516   ElGamal, 517   centralized, 546   centralized, 540   centralized, 546   centralized, 540   centralized, 540   centralized, 540   centralized, 540   centralized, 540   centralized, 540   centralized, 546   centralized, 540   centralized, 546   centralized, 540   centralized, 546   centralized,		· · · · · · · · · · · · · · · · · · ·
ElGamal, 517 encrypted key exchange (EKE), 538 Günther, 522 Güther, 522 Güther, 522 Güther, 522 Güther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key cultstering attack on block ciphers, 281 Key confirmation, 492 Key control, 494 Key control, 494 Key distribution, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–555 key layering, 551–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution pattern, 536 Key distribution poblem, 16, 546 Key distribution poblem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 Security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 intruder-in-the-middle, 530  enterleaving, 531 intruder-in-the-middle, 530  rentribution to key translation (center, 491  intruder-in-the-middle, 530  rentribution to key agreement, 652 definition of, 35, 544 Story Discource, 567–578 Iso 11166 standard, 652 Iso 11166 standard, 652 Iso 11166 standard, 653 Iso 11166 standard, 652 Iso 11166 standard, 653 Iso 11166 standard, 652 Iso 11168 tandard, 652 Iso 11168 standard, 652 Iso 11168 standard, 652 Iso		· · · · · · · · · · · · · · · · · · ·
encrypted key exchange (EKE), 538		· · · · · · · · · · · · · · · · · · ·
Günther, 522 MTI/A0, 517–519 relation to key transport, 491 Station-to-station (STS), 519 Key authentication, 492 Key clustering attack on block ciphers, 281 Key confirmation, 492 Key confirmation, 492 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530  definition of, 35, 544 ISO 8732 standard, 652 ISO 11568 tandard, 652 ISO 11568 standard, 652 ISO 11568 tandard, 652 ISO 1156 tandar		
MTI/A0, 517–519   ISO 8732 standard, 652     Station-to-station (STS), 519   ISO 10202-7 standard, 652     Key authentication, 492   ISO 11166 standard, 653     Key clustering attack on block ciphers, 281   ISO/IEC 11770 standard, 653     Key control, 494   Key agreement, see Key agreement key distribution, 490, 498   Key derivation, 490, 498   Key distribution     Key derivation, 490, 498   Key stablishment, see Key establishment key life cycle, 577–581   Key transport, see Key transport     Key day translation center, 553–554   Key management facility, 549     Key notarization, 568   Key pair, 12     authentication trees, 556–559   Key space, 11, 21, 224     Key distribution center (KDC), 491, 500, 547   Key distribution pattern, 536   Key translation center (KDC), 491, 500, 547   Key distribution pattern, 536   Key translation center (KDS), 505   Blom's KDS bound, 505   Security against coalitions, 505   Beller-Yacobi (2-pass), 514     Key establishment, 489–541   analysis of, 530–534, 540–541   attacks on interleaving, 531   intruder-in-the-middle, 530   relation to key agreement, 491		
relation to key transport, 491 Station-to-station (STS), 519 ISO 11166 standard, 652 Key authentication, 492 Key clustering attack on block ciphers, 281 Key control, 494 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution problem, 16, 546 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 attacks on interleaving, 531 intruder-in-the-middle, 530 ISO 11668 standard, 652 ISO 11568 standard, 653 ISO 11568 standard, 647 key agreement, see Key gareement key distribution, see Key distribution key establishment, see Key distribution key agreement, see Key distribution see Key distribution, see Key distribution see they distribution seen for liver and s		
Station-to-station (STS), 519 Key authentication, 492 Key clustering attack on block ciphers, 281 Key confirmation, 492 Key confirmation, 492 Key confirmation, 492 Key confirmation, 494 Key control, 494 Key distribution, see Key distribution Confidential keys, 551–555 Key layering, 551–553 Key translation center, 553–554 Symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antereaving, 531 intruder-in-the-middle, 530  ISO 11568 standard, 653 ISO 11568 standard, 653 ISO 11568 standard, 653 ISO 11568 standard, 653 ISO 11562 standard, 647 key agreement, see Key agreement, see Key distribution Rey agreement, see Key distribution, see Key distribution, see Key distribution schere, Key transport, see Key transport Key distribution schere, 555–555 key pre-distribution scheme, 540 definition of, 490 Key space, 11, 21, 224 Key tag, 568 Key translation center (KTC), 491, 500, 547, 553 Key transport, 35, 497–504, 506–515, 535–536 Key distribution system (KDS), 505 Beller-Yacobi (2-pass), 514 Beller-Yacobi (2-pass), 514 Key establishment, 489–541 Analysis of, 530–534, 540–541 An		
Key authentication, 492 Key clustering attack on block ciphers, 281 Key confirmation, 492 Key confirmation, 494 Key control, 494 Key control, 494 Key distribution, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530 ISO/IEC 11770 standard, 647 Iso/IEC 11770 standard, 646 Iso/IEC 11770 standard, 642 Iso/IEC 11770 s		
Key clustering attack on block ciphers, 281 Key confirmation, 492 Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–555 key layering, 551–555 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530 ikey distribution key key distribution, see Key distribution scheme, 540 key agreement, see Key distribution, see Key distribution, 568 key diffication, 568 key management facility, 549 Key pre-distribution scheme, 540 definition of, 420 Key pre-distribution scheme, 540 definition of, 490 Key sapace, 11, 21, 224 Key transport, 35, 497–504, 506–515, 535–536 Key distribution problem, 16, 546 Key transport, 35, 497–504, 506–515, 535–536 Key distribution system (KDS), 505 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 definition of, 490 Key establishment, 489–541 analysis of, 530–534, 540–541 Needham-Schroeder public-key, 508 niterleaving, 531 intruder-in-the-middle, 530 relation to key agreement, 491		
Key confirmation, 492 Key control, 494 Key derivation, 490, 498 Key distribution Confidential keys, 551–555 key layering, 551–553 key transport, see Key transport Key distribution center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530 key distribution key agreement, see Key distribution see Key distribution, see Key distribution see Key transport key distribution senter, 536 Key apare, 12 Key pair, 12 Key server, 549 definition of, 490 Key server, 549 Key space, 11, 21, 224 Key tag, 568 Key transport, 35, 497–504, 506–515, 535–536 Key distribution system (KDS), 505 AKEP1, 499 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 Beller-Yacobi (4-pass), 513 COMSET, 536 definition of, 490 Kerberos, 501–502 Needham-Schroeder public-key, 508 attacks on interleaving, 531 intruder-in-the-middle, 530 relation to key agreement, 491		
Key control, 494 Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key establishment, see Key distribution, see Key distribution, see Key destribution, see Key distribution, see Key distribution, see Key destribution, see Key destribution, see Key distribution, see Key expert see Key transport, see Key transport Key management facility, 549 Key notarization, 568 key pair, 12 Key pair, 12 Key pre-distribution scheme, 540 definition of, 490 definition of, 490 Key server, 549 Key space, 11, 21, 224 Key translation center (KTC), 491, 500, 547, 553 Key distribution problem, 16, 546 Key transport, 35, 497–504, 506–515, 535–536 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 Beller-Yacobi (2-pass), 514 Key establishment, 489–541 analysis of, 530–534, 540–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530 Revice of the cycle, 577–581 key transport, see Key transport, see Key transport, see Key transport, see Key transport see, they management facility, 549 Key translation center (KDC), 491, 500, 547, 553 Key translation center (KTC), 491, 500, 547 Key translati		•
Key derivation, 490, 498 Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, see Key establishment key life cycle, 577–581 key life cycle, 577–581 key life cycle, 577–581 key transport, see Key transport key management facility, 549 Key management facility, 549 Key notarization, 568 Key pair, 12 key notarization, 568 Key pair, 12 key pre-distribution scheme, 540 definition of, 490 Key server, 549 Key server, 549 Key sapace, 11, 21, 224 Key transport, see Key transport key management facility, 549 Key server, 549 key notarization, 568 Key pair, 12 key notarization, 568		
Key distribution confidential keys, 551–555 key layering, 551–553 key translation center, 553–554 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key gare, 11, 21, 224 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution pattern, 536 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530  key distributio key key transport, 364 key translation center (KTC), 491, 500, 547, 553 key distribution of, 490 key translation center (KTC), 491, 500, 547, 553 Key distribution of, 505 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 Beller-Yacobi (4-pass), 513 COMSET, 536 COMSET, 536 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530  key life cycle, 577–581 key transport, see Key transport key management facility, 549 key notarization, 568 key paet, 11, 21, 224 key perdistribution of, 490 key space, 11, 21, 224 key pre-distribution of, 490 key translation center (KTC), 491, 500, 547, 553 key translation center (KTC), 491, 500, 547, 553 key translation center (KTC), 491, 500, 547, 553 key translation, 549 key paet, 12 key perdistribution of, 490 key translation, 549 key paet, 12 key		
confidential keys, 551–555 key layering, 551–553 key transport, see Key transport key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530 Key agreement, 491 Key aggreement, 491 Key aggreement, 491 Key aggreement, 491 Key aggreement, 491		
key layering, 551–553 key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution system (KDS), 505 Blom's KDS bound, 505 Blom's KDS bound, 505 Security against coalitions, 505 Key escrow, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 intruder-in-the-middle, 530 Key management facility, 549 Key notarization, 568 key notarization, 568 key notarization, 568 key notarization, 568 key paient, 642, 658 key paient, 640 key space, 11, 21, 224 key tag, 568 key tanslation center (KTC), 491, 500, 547, 553 key tag, 68 key tanslation sys		
key translation center, 553–554 symmetric-key certificates, 554–555 public keys, 555–566 authentication trees, 556–559 certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 Security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key escrow, 584–541 analysis of, 530–534, 540–541 anticleaving, 531 intruder-in-the-middle, 530 Key distribution to center, 553 Key distribution problem, 16, 546 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key escrow, 584–581 attacks on interleaving, 531 intruder-in-the-middle, 530 Key notarization, 568 Key patent, 642, 658 Key pair, 12 Key per-distribution scheme, 540 definition of, 490 Key server, 549 Key server, 549 Key sace, 11, 21, 224 Key tag, 568 Key translation center (KTC), 491, 500, 547, 553 Key transport, 35, 497–504, 506–515, 535–536 Key translation center (KTC), 491, 500, 547, 553 Key translation of, 490 Key escrow, 584–586 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 Rey translation ocenter (KTC), 491, 500, 547 Key tag, 568 Key translation ocen		
symmetric-key certificates, 554–555 public keys, 555–566		
public keys, 555–566     authentication trees, 556–559     certificates, 559–561     identity-based, 561–562     implicitly-certified, 562–563     Key server, 549     implicitly-certified, 562–563     Key distribution center (KDC), 491, 500, 547     Key distribution pattern, 536     Key distribution problem, 16, 546     Key distribution system (KDS), 505     Blom's KDS bound, 505     security against coalitions, 505     Rey escrow, 584–586     agent, 550, 584     Clipper, 584     Key establishment, 489–541     analysis of, 530–534, 540–541     anterleaving, 531     interleaving, 531     intruder-in-the-middle, 530     Key server, 549     Key server, 549     Key space, 11, 21, 224     Key space, 11, 21, 224     Key stag, 568     Key translation center (KTC), 491, 500, 547, 553     Key transport, 35, 497–504, 506–515, 535–536      Key transport, 35, 497–504, 506–515, 535–536      Key transport, 35, 497–504, 506–515, 535–536      Key transport, 35, 497–504, 506–515, 535–536      Key transport, 35, 497–504, 506–515, 535–536      Key transport, 35, 497–504, 506–515, 535–536      Key transport, 35, 497–5		
authentication trees, 556–559 certificates, 559–561 definition of, 490 Key server, 549 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 Clipper, 584 Clipper, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 interleaving, 531 interleaving, 531 interleaving, 531 interleaving definition of, 490 key server, 549 Key server, 549 Key sapace, 11, 21, 224 Key stag, 568 Key translation center (KTC), 491, 500, 547, 553 Key transport, 35, 497–504, 506–515, 535–536 Key transport, 35, 497–504, 506–515, 536 Key transport, 35, 497–504, 506–515, 506 Key transport, 35, 497–504, 506–		
certificates, 559–561 identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 intruder-in-the-middle, 530 Key server, 549 Key server, 549 Key sapace, 11, 21, 224 Key sapace, 11, 21, 224 Key sapace, 11, 21, 224 Key stag, 568 Key translation center (KTC), 491, 500, 547, 553 Key transport, 35, 497–504, 506–515, 535–536 Key transport, 36, 497–504, 500, 547, 553 Key transport, 36, 500, 547, 553 Key transport		
identity-based, 561–562 implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 Clipper, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 anticleaving, 531 interleaving, 531 interleaving, 531 interleaving, 530  Key stag, 568 Key space, 11, 21, 224 Key stag, 568 Key tag, 568 Key tag, 568 Key translation center (KTC), 491, 500, 547, 553 Key tag, 568 Key transport, 35, 497–504, 506–515, 535–536 Key transport, 35, 497–504, 506–515, 536 Key transport, 35, 497–504, 506–515, 536 Key transport, 35, 497–504, 506–515, 536 Key transport, 35, 497–504		• •
implicitly-certified, 562–563 Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 Clipper, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 anticks on interleaving, 531 intruder-in-the-middle, 530 Key stag, 568 Key transport, 35, 497–504, 506–515, 535–536 AKEP1, 499 Beller-Yacobi (2-pass), 514 COMSET, 536 definition of, 4-pass), 513 COMSET, 536 definition of, 490 Key establishment, 489–541 Needham-Schroeder public-key, 508 Needham-Schroeder shared-key, 503 Otway-Rees protocol, 504 relation to key agreement, 491		
Key distribution center (KDC), 491, 500, 547 Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 anticks on interleaving, 531 intruder-in-the-middle, 530 Key transport, 35, 497–504, 506–515, 535–536 AKEP1, 499 AKEP1, 499 AKEP2, 499 Beller-Yacobi (2-pass), 514 COMSET, 536 COMSET, 536 definition of, 490 Kerberos, 501–502 Needham-Schroeder public-key, 508 Needham-Schroeder shared-key, 503 Otway-Rees protocol, 504 relation to key agreement, 491		-
Key distribution pattern, 536 Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 Clipper, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 intruder-in-the-middle, 530 Key transport, 35, 497–504, 506–515, 535–536 Key transport, 35, 497–504, 506–515, 535–536 Key transport, 35, 497–504, 506–515, 535–536 AKEP1, 499 AKEP2, 499 Beller-Yacobi (2-pass), 514 Beller-Yacobi (4-pass), 513 COMSET, 536 definition of, 490 Kerberos, 501–502 Needham-Schroeder public-key, 508 Needham-Schroeder shared-key, 503 Otway-Rees protocol, 504 relation to key agreement, 491		· ·
Key distribution problem, 16, 546 Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Key escrow, 584–586 agent, 550, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 antacks on interleaving, 531 intruder-in-the-middle, 530  Key transport, 35, 497–504, 506–515, 535–536 AKEP1, 499 Beller-Yacobi (2-pass), 514 Beller-Yacobi (4-pass), 513 COMSET, 536 COMSET, 536 definition of, 490 Kerberos, 501–502 Needham-Schroeder public-key, 508 Needham-Schroeder shared-key, 503 Otway-Rees protocol, 504 relation to key agreement, 491		
Key distribution system (KDS), 505 Blom's KDS bound, 505 security against coalitions, 505 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 Beller-Yacobi (4-pass), 513 agent, 550, 584 Clipper, 584 Clipper, 584 Key establishment, 489–541 analysis of, 530–534, 540–541 analysis of, 530–534, 540–541 niterleaving, 531 interleaving, 531 interleaving, 530 interleaving, 530 relation to key agreement, 491		
Blom's KDS bound, 505 security against coalitions, 505 Beller-Yacobi (2-pass), 514 Key escrow, 584–586 Beller-Yacobi (4-pass), 513 agent, 550, 584 Clipper, 584 Clipper, 584 Key establishment, 489–541 Analysis of, 530–534, 540–541 Attacks on Interleaving, 531 Interleaving, 531 Intruder-in-the-middle, 530  AKEP2, 499 Beller-Yacobi (2-pass), 514 COMSET, 536 COMSET, 536  Kerberos, 501–502 Needham-Schroeder public-key, 508 Needham-Schroeder shared-key, 503 Otway-Rees protocol, 504 relation to key agreement, 491		-
security against coalitions, 505  Rey escrow, 584–586  agent, 550, 584  Clipper, 584  Clipper, 584  Key establishment, 489–541  analysis of, 530–534, 540–541  attacks on  interleaving, 531  intruder-in-the-middle, 530  Reller-Yacobi (2-pass), 514  Beller-Yacobi (2-pass), 514  Reller-Yacobi (2-pass), 513  Reller-Yacobi (2-pass), 513  Reller-Yacobi (2-pass), 514  Reller-Yacobi (4-pass), 513		
Key escrow, 584–586    agent, 550, 584    Clipper, 584    Clipper, 584    definition of, 490    Key establishment, 489–541    analysis of, 530–534, 540–541    antacks on    interleaving, 531    intruder-in-the-middle, 530    Beller-Yacobi (4-pass), 513    NeOMSET, 536    Kerberos, 501–502    Needham-Schroeder public-key, 508    Needham-Schroeder shared-key, 503    Otway-Rees protocol, 504    relation to key agreement, 491		
agent, 550, 584 Clipper, 584 Clipper, 584 Clipper, 584 Key establishment, 489–541 Analysis of, 530–534, 540–541 Attacks on Aniterleaving, 531 Aniterleaving, 531 Aniterleaving, 530 Anit	· ·	* *
Clipper, 584 definition of, 490 Key establishment, 489–541 Kerberos, 501–502 analysis of, 530–534, 540–541 Needham-Schroeder public-key, 508 attacks on Needham-Schroeder shared-key, 503 interleaving, 531 Otway-Rees protocol, 504 intruder-in-the-middle, 530 relation to key agreement, 491	•	
analysis of, 530–534, 540–541  attacks on  interleaving, 531  intruder-in-the-middle, 530  Needham-Schroeder public-key, 508  Needham-Schroeder shared-key, 503  Otway-Rees protocol, 504  relation to key agreement, 491		definition of, 490
attacks on Needham-Schroeder shared-key, 503 interleaving, 531 Otway-Rees protocol, 504 intruder-in-the-middle, 530 relation to key agreement, 491	**	
attacks on Needham-Schroeder shared-key, 503 interleaving, 531 Otway-Rees protocol, 504 intruder-in-the-middle, 530 relation to key agreement, 491	- · · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·
interleaving, 531 Otway-Rees protocol, 504 intruder-in-the-middle, 530 relation to key agreement, 491		
intruder-in-the-middle, 530 relation to key agreement, 491	interleaving, 531	<del>-</del>
	misplaced trust in server, 531	Shamir's no-key protocol, 500

X.509 three-way, 512	strong, 139
X.509 two-way, 511	Life cycle, see Key life cycle
Key update, 490	Linear code, 506
Keyed hash function, see Message authentication	Linear combination, 80
code (MAC)	Linear complexity, 198–201
Keying material, 544	algorithm for computing, see Berlekamp-
Keying relationship, 544	Massey algorithm
Keystream, 20, 193, 194	of a finite sequence, 198
Keystream generator, 21, 194	of a random periodic sequence, 199
Khafre block cipher, 271	of a random sequence, 198
attacks on, 281	of an infinite sequence, 198
patent, 644	profile, 199
Khufu block cipher, 271	Linear complexity profile, 199–200
attacks on, 281	algorithm for computing, 201
patent, 644	limitations of, 200
Knapsack generator, 209, 220	of a random sequence, 199
Knapsack problem, 131	Linear congruential generator, 170, 187
Knapsack public-key encryption, 300–306	multivariate congruential generator, 187
Chor-Rivest, 302–306	truncated, 187
Merkle Hellman, 300–302	Linear consistency attack, 219–220
Knapsack set, 117	Linear cryptanalysis
density of, 120	of block ciphers, 258, 271, 278, 280
Known-key attack, 42, 496, 534	of stream ciphers, 219
Known-key triangle attack, 538	Linear feedback shift register (LFSR), 195–201
Known-message attack, 432	connection polynomial of, 196
Known-plaintext attack, 41, 225	definition of, 195
KryptoKnight, 535, 541	delay element of, 195
KTC, see Key translation center (KTC)	feedback bit of, 196
_	initial state of, 196
$\mathbf{L}_{\mathbf{L}}$	maximum-length, 197
$L^3$ -lattice basis reduction algorithm, 118–120, 131	non-singular, 196
Lagrange's theorem, 76	output sequence of, 195
Lambda method for discrete logarithms, 128	stage of, 195
Lamport's one-time-password scheme, 396	Linear sieve, 128
Lanczos method, 129	Linear syndrome attack, 218
Lattice, 118	Linear system (solving large), 129
dimension of, 118	Linearly dependent, 80
reduced basis, 118	Linearly independent, 80
Lattice basis reduction algorithm, 118–120, 131, 317	LION block cipher, 282
Law of large numbers, 52	Little-endian, 344
Law of quadratic reciprocity, 72	Little-o notation, 59
lcm, see Least common multiple	Lock-in, 221
Leading coefficient, 78	Logarithm, 49
LEAF, 584–585	LOKI block cipher, 281
Leaf of a binary tree, 557	LOKI'89, 281
Least common multiple, 64	LOKI'91, 270, 281
Least significant digit, 593	Long-term key, 553
Legendre symbol, 72	Low-order digit, 593
computing, 73	Luby-Rackoff block cipher, 282
Lehmer's gcd algorithm, 607–608, 632	LUC cryptosystem, 314
Length of a vector, 118	LUCDIF, 316
Liar, 135	LUCELG, 316
Euler, 138	Lucas-Lehmer primality test, 142
Fermat, 136	Lucifer block cipher, 276

patent, 641, 659	Merkle one-time signature scheme, 464–466, 485 authentication tree, 466
M	key generation, 464
<i>m</i> -sequence, 197	patent, 643
MAC, see Message authentication code (MAC)	security of, 465
Manipulation detection code, see Modification de-	signature generation, 465
tection code	signature verification, 465
Mapping, 6, 50	Merkle puzzle scheme, 47, 537
Markov cipher, 280	Merkle's DES-based hash function, 338, 339, 378
MASH-1 hash function, 352	Merkle's meta-method for hashing, 333
ISO/IEC 10118-4 standard, 647	Merkle-Hellman knapsack encryption, 300–302,
MASH-2 hash function, 352	317–318
ISO/IEC 10118-4 standard, 647	basic
Master key, 551	decryption algorithm, 301
Matyas-Meyer-Oseas hash function, 341	encryption algorithm, 301
ISO/IEC 10118-2 standard, 647	key generation, 300
Maurer's algorithm for provable prime generation,	multiple-iterated
153, 167	key generation, 302
Maurer's universal statistical test, 183–185, 189	patent, 637
Maximum order complexity, 217	security of, 302
Maximum-length LFSR, 197	Mersenne number, 142
Maximum-rank-distance (MRD) code, 317	Mersenne prime, 142, 143, 160
McEliece public-key encryption, 298–299, 317	Message authentication, see Data origin authenti-
decryption algorithm, 299	cation
encryption algorithm, 299	Message authentication code (MAC), 33, 323,
key generation, 298	352–359, 381–383
recommended parameter sizes, 299	applications of, 323, 330
security of, 299	based on block ciphers, 353–354
MD-strengthening, 334, 335, 337	CBC-MAC, see CBC-MAC
MD2 hash function, 380	CFB-64 MAC, 650
RFC 1319, 655	RIPE-MAC, see RIPE-MAC
MD4 hash function, 346	birthday attack on, 352
RFC 1320, 655	customized, 356–358
MD5 hash function, 347	bucket hashing, 382
RFC 1321, 655	MD5-MAC, 358
MD5-MAC, 358	Message Authenticator Algorithm
MDC, see Modification detection code	(MAA), 356
MDC-2 hash function, 342	definition, 325
ISO/IEC 10118-2 standard, 647	for stream ciphers, 358–359
patent, 639	CRC-based, 359
MDC-4 hash function, 343	Lai-Rueppel-Woollven scheme, 383
patent, 639	Taylor's scheme, 383
MDS code, 281, 506	from MDCs, 354–355
Mean, 51	envelope method with padding, 355
Measure of roughness, 249	hash-based MAC, 355
Mechanism, 34	HMAC, 355
Meet-in-the-middle attack	secret prefix method, 355
on double DES, 235	secret suffix method, 355
on double encryption, 235	XOR MAC, 382
time-memory tradeoff, 236	ISO 8730 standard, 652
on multiple encryption	ISO 9807 standard, 652
time-memory tradeoff, 236	properties of
Meet-in-the-middle chaining attack, 374	compression, 325
Merkle channel, 48	computation-resistance, 325

ease of computation, 325	Mono-alphabetic substitution cipher, see Substitu
key non-recovery, 325	tion cipher
retail MAC, 650	Monobit test, 181
types of attack	Monotone access structure, 527
adaptive chosen-text, 326	Montgomery exponentiation, 619–620
chosen-text, 326	Montgomery multiplication, 602–603
known-text, 326	Montgomery reduction, 600–602, 631
types of forgery	MOSS, 656
existential, 326	RFC 1848, 656
selective, 326	Most significant digit, 593
see also CBC-MAC	MTI protocols, 518, 537
Message authentication tag system, 376	MTI/A0 key agreement, 517-519, 537
Message Authenticator Algorithm (MAA), 356	Goss variant, 537
ISO 8731-2 standard, 652	patent, 644, 659
Message concealing in RSA, 290, 313	Multi-secret threshold scheme, 527
Message digest, 321	Multiple encryption, 234–237
Message integrity code (MIC), 323	definition of, 234
Message space, 11	double encryption, 234
Message-independent key establishment, 493	modes of operation, 237
Micali-Schnorr pseudorandom bit generator, 186	triple-inner-CBC mode, 237
Miller-Rabin primality test, 139, 165	triple-outer-CBC mode, 237
MIME, 656, 661	triple encryption, 235
Minimum disclosure proof, 421	E-D-E, 235
Minimum polynomial, 156	two-key triple-encryption, 235
Mips year, 126	Multiple polynomial quadratic sieve, 97
MISSI, 590	Multiple-precision integer, 593
Mixed-radix representation, 611, 630	Multiple-precision integer arithmetic, 592–599
Mixing algebraic systems, 279	addition, 594–595
Miyaguchi-Preneel hash function, 341	division, 598–599
Möbius function, 154	normalization, 599
mod notation, 64	gcd, see Greatest common divisor
Modes of operation	multiplication, 595–596
multiple modes, <i>see</i> Multiple encryption, modes	discrete Fourier transform (DFT), 631
of operation	Karatsuba-Ofman, 630
single modes, see Block cipher, modes of op-	squaring, 596–597
eration	subtraction, 594–595
Modification detection code (MDC), 33, 323, 324	Multiple-precision modular arithmetic, 599–606
Modified-Rabin pseudorandom bit generator, 190	addition, 600
Modified-Rabin signature scheme, 439–442, 482 key generation, 440	exponentiation, <i>see</i> Exponentiation inversion, 610
security of, 441	multiplication
signature generation, 440	classical, 600
signature verification, 440	Montgomery multiplication, 602–603
Modular arithmetic, see Multiple-precision modu-	reduction, 599
lar arithmetic	Barrett, 603–605, 631
Modular exponentiation, see Exponentiation	Montgomery, 600–602, 631
Modular reduction, 599	special moduli, 605–606
Barrett, 603–605, 631	subtraction, 600
Montgomery, 600–602, 631	Multiplexer generator, 220
special moduli, 605–606	Multiplicative group
Modular representation, see Mixed-radix represen-	of $\mathbb{Z}_n$ , 69
tation	of a finite field, 81
Modulus, 67	Multiplicative inverse, 68
Monic polynomial, 78	computing, 71, 84, 610

Multiplicative property in RSA, 288, 435, 482 Multiplicity of a factor, 122	Number field sieve for discrete logarithms, 128
Multispeed inner-product generator, 220	for integer factorization, 98, 126
Multivariate polynomial congruential generator,	implementation reports, 126, 127
187	general number field sieve, 98
Mutual authentication, 387, 402, 405, 494	special number field sieve, 98, 126
Mutual information, 57	Number theory, 63–75
Mutually exclusive events, 51	Nyberg-Rueppel signature scheme, 460–462, 485
•	security of, 461
N	signature generation, 461
N-Hash function, 380	signature verification, 461
Name server, 549	
Needham-Schroeder public-key, 508, 536	0
Needham-Schroeder shared-key, 401, 503, 535	Object identifier (OID), 660
Next-bit test, 171	OFB, see Output feedback mode
Next-discrepancy, 200	Off-line trusted third party, 548
Nibble, 443	Ohta-Okamoto identification protocol, 422
NIST, 654	On-line certificate, 576
Noise diode, 40	On-line trusted third party, 547
Non-interactive protocol, 493	On-line/off-line signature, 486
Non-interactive ZK proof, 424	patent, 644
Non-malleable encryption, 311, 319	One-key encryption, 15
Non-repudiation, 3, 4, 582–584	One-sided statistical test, 179
ISO/IEC 13888 standard, 648	One-time insider, 496
Non-singular	One-time pad, 21, 192–193, 274
FSR, 203	patent, 657
LFSR, 196	One-time password scheme, 395–397
Nonce, 397, 497	One-time signature scheme, 462–471
Nonlinear combination generator, 205–208	Diffie-Lamport, 485
combining function of, 205	GMR, 468–471
Nonlinear feedback shift register, see Feedback shift	Merkle, 464–466
register (FSR)	Rabin, 462–464
Nonlinear filter generator, 208–209	validation parameters, 462
filtering function, 208	One-to-one function, 7–8, 50
Nonlinear order, 205	One-way cipher, 377
Normal basis, 168	One-way function, 8–9, 327
exponentiation, 642	DES-based, 190, 328
multiplication, 642	exponentiation modulo a prime, 115, 329
patents, 642–643, 659	multiplication of large primes, 329
Normal distribution, 176–177	Rabin function, 115
mean of, 176	RSA function, 115
standard, 176	One-way hash function (OWHF), 325
variance of, 176	One-way permutation, 115, 328
Normal polynomial, 168	Onto function, 7, 50
Normalization, 599	Open Systems Interconnection (OSI), 653, 660
Notarized key, 569	Operational, 532
Notary	Opponent, 13, 495
agent, 550	see also Attacker
seal, 569	Optimal normal basis, 168, 659
service, 582	Oracle, 88
NP, 60	Order
NP-complete, 61	generating element of maximum order in $\mathbb{Z}_n^*$
NP-hard, 62	163
NPC, 61	of $\mathbb{Z}_n^*$ , 69
	$n, \dots$

of a finite field, 80	Perfect secrecy, 42, 227, 307
of a group, 75	Perfect secret sharing scheme, 526, 527
of a group element, 76, 160	Perfect zero-knowledge protocol, 407
algorithm for determining, 162	Period of a periodic sequence, 180
of an element in $\mathbb{Z}_n^*$ , 69	Periodic sequence, 180
Otway-Rees protocol, 504, 536	autocorrelation function of, 180
Output feedback mode (OFB), 232–233	cycle of, 180
as a stream cipher, 233	period of, 180
changing IV in, 232	Permanent insider, 496
counter mode, 233	Permutation, 10, 50
feedback size, 233	Permutation polynomial, 314
Outsider, 496	Permuted kernel problem, 423
OWHF, see One-way hash function	Personal Identification Number (PIN)
Ownership, 3	ANSI X9.8 standard, 649
r, -	ISO 9564 standard, 652
P	PGP, see Pretty Good Privacy (PGP)
<b>P</b> , 60	Phi function $(\phi)$ , 65
Palindromic keys of DES, 257	Photuris, 661
Party, 13	Physically secure channel, 13
Passcode generator, 402	PIKE stream cipher, 222
Passive adversary, 15	PIN, see Passwords (weak authentication), see Per-
Passive attack, 41, 495	sonal Identification Number (PIN)
Passkey, 395	PKCS standards, 656, 661
Passphrase, 390	
Passwords (weak authentication), 388–397, 420	ordering and acquiring, 657
aging, 390	PKCS #1, 445–447, 483
attacks on, 391–393	Plaintext, 11
dictionary, 392	Plaintext-aware encryption scheme, 311–312
	Playfair cipher, 239, 274
exhaustive search, 391	Pless generator, 218
password-guessing, 392	PN-sequence, 181
pre-play, 397	Pocklington's theorem, 144
replay, 391	Pohlig-Hellman algorithm, 107–109, 128
encrypted password file, 389	Pohlig-Hellman cipher, 271
entropy, 392	patent, 642, 659
generator, 387	Poker test, 182, 188
one-time, 395–397	Policy Certification Authority (PCA), 589
Lamport's scheme, 396	Pollard's $p-1$ algorithm, 92–93, 125
passkey, 395	Pollard's rho algorithm
passphrase, 390	for discrete logarithms, 106–107, 128
personal identification number (PIN), 394	for factoring, 91–92, 125
rules, 389	Polyalphabetic substitution cipher, 18, 241–242,
salting, 390	273–274
stored password file, 389	auto-key cipher, 242
unix, 393–394	Beaufort cipher, 241
Patents, 635–645, 657–659	cipher machine, see Cipher machine
ordering and acquiring, 645	PURPLE cipher, 276
priority date, 636	Vigenère cipher
validity period, 636	auto-key, 242
PEM, see Privacy Enhanced Mail (PEM)	compound, 241
Pepin's primality test, 166	full, 242
Perceptrons problem, 423	running-key, 242
Perfect forward secrecy, 496, 534	simple, 18, 241
Perfect power	single mixed alphabet, 242
testing for, 89	Polygram substitution eigher 239

Polynomial, 78	Principal square root, 74
irreducible, 78	Privacy, see Confidentiality
leading coefficient of, 78	Privacy Enhanced Mail (PEM), 588, 655
Polynomial basis, 83	RFCs 1421–1424, 655
Polynomial factorization, 122–124, 132	Private key, 26, 27, 544
Berlekamp's Q-matrix algorithm, 124	Private-key certificate, see Symmetric-key certifi-
square-free factorization, 123	cate
Polynomial-time algorithm, 59	Private-key encryption, 15
Polynomial-time indistinguishability, 318	Probabilistic public-key encryption, 306–312,
Polynomial-time statistical test, 171	318–319
Polynomially security public-key encryption, 306	Blum-Goldwasser, 308-311
Polytime reduction, 61, 88	Goldwasser-Micali, 307–308
Practical security, 43	security level
Pre-play attack, 397, 398	polynomially secure, 306
Pre-positioned secret sharing scheme, 527	semantically secure, 306
Precision, 593	Probability, 50
Preimage, 6, 50	Probability density function, 176
Preimage resistance, 323	Probability distribution, 50
Pretty Good Privacy (PGP), 661	Probability theory, 50–55
Primality proving algorithm, <i>see</i> Primality test, true	Probable prime, 136
primality test	Product cipher, 20, 251
Primality test	Proof of knowledge, 406, 421, 422
probabilistic primality test, 135–142	Proposed Encryption Standard (PES), 279
comparison, 140–142	Protection lifetime, 553, 578
Fermat's test, 136	Protocol
Miller-Rabin test, 139	authentication, 493
,	
Solovay-Strassen test, 138	cut-and-choose, 410, 421
true primality test, 142–145	definition of, 33, 490
Atkin's test, 145	failure of, 34
Goldwasser-Kilian test, 166	hybrid, 512
Jacobi sum test, 144	identification, see Identification
Lucas-Lehmer test, 142	key establishment, see Key establishment
Pepin's test, 166	message-independent, 493
Prime number, 9, 64	non-interactive, 493
Prime number generation, 145–154	witness hiding, 423
algorithms	zero-knowledge, 405–417
Gordon's algorithm, 150	Provable prime, 134, 142
Maurer's algorithm, 153	Provable security, 43, 533
NIST method, 151	Prover, 386
random search, 146	Pseudo-collision, 371
DSA primes, 150–152	Pseudo-Hadamard transform, 266
incremental search, 148	Pseudo-noise sequence, 181
provable primes, 152–154	Pseudoprime, 136
random search, 145–149	Euler, 138
strong primes, 149–150	strong, 139
Prime number theorem, 64	Pseudorandom bit generator (PRBG), 173–175
Primitive element, see Generator	ANSI X9.17, 173
Primitive normal polynomial, 168	definition of, 170
Primitive polynomial, 157–160	FIPS 186, 174–175
algorithm for generating, 160	linear congruential generator, 170, 187
algorithm for testing, 157	Pseudorandom bit sequence, 170
definition of, 84	Pseudorandom function, 331
Primitives, 4	Pseudorandom sequences, 39-41
Principal, 495	Pseudosquares modulo $n$ , 74, 99, 308

Public key, 26, 27, 544	signature generation, 438
compared vs. symmetric-key, 31–32, 551	signature verification, 439
implicitly-certified, 520–522	use of redundancy, 439
Public-key certificate, 39, 559–561, 587	Rabin's information dispersal algorithm (IDA),
data part, 559	539
distinguished name, 559	RACE/RIPE project, 421, 536
signature part, 559	Radix representation, 592–593
Public-key encryption, 25–27, 283–319	base b, 592
advantages of, 31	binary, 592
disadvantages of, 32	high-order digit, 593
ElGamal, 294–298	least significant digit, 593
knapsack, 300–306	low-order digit, 593
Chor-Rivest, 302–306	mixed, 611, 630
Merkle-Hellman, 300–302	most significant digit, 593
LUC, see LUC cryptosystem	precision, 593
McEliece, 298–299	radix $b$ , 592
non-malleable, 311	Ramp schemes, see Secret sharing
plaintext-aware, 311–312	Random bit generator, 39–41, 171–173
probabilistic, 306–312	cryptographically secure pseudorandom bit
Blum-Goldwasser, 308–311	generator, see Cryptographically sec
Goldwasser-Micali, 307–308	ure pseudorandom bit generator
Rabin, 292–294	(CSPRBG)
reversible, 28	definition of, 170
RSA, 285–291	hardware techniques, 172
types of attacks, 285	pseudorandom bit generator, see Pseudorand
Williams, 315	om bit generator (PRBG)
PURPLE cipher, 276	software techniques, 172
Puzzle system, 376, 537	Random cipher, 225
	Random cipher model, 246
Q	Random function, 190
Quadratic congruential generator, 187	poly-random, 190
Quadratic non-residues, 70	Random mappings model, 54
Quadratic residues, 70	Random oracle model, 316
Quadratic residuosity problem, 99, 127, 307	Random square methods, 94-98
Quadratic sieve factoring algorithm, 95–97, 126	Random variable, 51
implementation reports, 126	continuous, 176
Quantum computer, 130	entropy of, 56
Quantum cryptography, 48, 535	expected value of, 51
Quotient, 64, 78	mean of, 51
_	standard deviation of, 51
R	variance of, 51
Rabin one-time signature scheme, 462–464	Randomized algorithm, 62–63
key generation, 463	Randomized DES (RDES) block cipher, 278
resolution of disputes, 463	Randomized encryption, 225, 296, 306
signature generation, 463	Randomized stream cipher, 216
signature verification, 463	Range of a function, 46
Rabin public-key encryption, 292–294, 315	Rate of an iterated hash function, 340
decryption algorithm, 292	Rational numbers, 49
encryption algorithm, 292	RC2 block cipher, 282
key generation, 292	RC4 stream cipher, 222, 282
security of, 293	RC5 block cipher, 269–270, 280–281
use of redundancy, 293	attacks on, 280–281
Rabin signature scheme, 438–442, 482	decryption algorithm, 270
ISO/IEC 9796, 442–444	encryption algorithm, 270
key generation, 438	oner priori argoritani, 270

<sup>©1997</sup> by CRC Press, Inc. — See accompanying notice at front of chapter.

key schedule, 270	encryption exponent, 286
patent, 659	key generation, 286
test vectors, 270	modulus, 286
weak keys, 281	patent, 638
Real number, 49	prime selection, 290
Real-time, 385	recommended modulus size, 290
Reblocking problem in RSA, 435–436, 482	security of, 287–290
Receipt, 3	adaptive chosen-ciphertext attack, 289,
Receiver, 13	313
Reduced basis, 118	common modulus attack, 289
Redundancy, 29, 431	cycling attacks, 289, 313
of English, 245	forward search attack, 288
Reflection attack, 417, 530, 540	message concealing, 290, 313
Registration authority, 549	multiplicative properties, 288
Related-key attack on block ciphers, 281	polynomially related plaintext, 313
Relatively prime, 64	relation to factoring, 287
Remainder, 64, 78	small decryption exponent, 288
Replay attack, 42, 417	small encryption exponent, 288, 291, 313
Requests for Comments, see RFCs	unbalanced, 314
Residue list sieve, 128	RSA signature scheme, 433–438, 482
Resilient key establishment protocol, 532	ANSI X9.31-1 standard, 651
Response, 409	bandwidth efficiency, 437
Retail banking, 648	ISO/IEC 9796, 442–444
Retail MAC, 650	key generation, 434
Reverse certificate, 575	patent, 638
Reversible public-key encryption scheme, 28	PKCS #1, 445–447
Revocation, 3	reblocking problem, 435–436, 482
RFCs, 655–656	redundancy function, 437
ordering and acquiring, 657	security of, 434–435
Ring, 76–77	signature generation, 434, 613
commutative, 77	signature verification, 434
definition of, 76	Run of a sequence, 180
group of units, 77	Running key generator, 194
polynomial, 78–79	Runs test, 182, 188
Rip van Winkle cipher, 216	
RIPE-MAC, 354, 381	$\mathbf{S}$
RIPEMD hash function, 380	S/MIME, 661
RIPEMD-128 hash function, 339, 380	Safe prime, 537
RIPEMD-160 hash function, 339, 350	algorithm for generating, 164
ISO/IEC 10118-3 standard, 647	definition of, 164
Root vertex, 557	SAFER block cipher, 266–269, 280
Rotor-based machine, see Cipher machine	attacks on, 280
Round function, 251	SAFER K-64 decryption algorithm, 269
Round of a product cipher, 20	SAFER K-64 encryption algorithm, 268
<b>RP</b> , 63	SAFER K-64 key schedule, 268
RSA-129 number, 126, 130	SAFER K-128, 280
RSA problem, 98–99, 127, 287	SAFER SK-64 key schedule, 268
security of individual bits, 116	SK-128, 280
RSA pseudorandom bit generator, 185–186	test vectors, 269
RSA public-key encryption, 285–291, 312–315	Salt, 288, 390
decryption algorithm, 286, 611, 613	Schnorr identification protocol, 414-416, 422
decryption exponent, 286	patent, 639
elliptic curve analogue, 315	Schnorr signature scheme, 459-460, 484
encryption algorithm, 286	Brickell-McCurley variant, 484

Okamoto variant, 484	pseudo-noise, 181
patent, 639	run of, 180
signature generation, 459	Sequence numbers, 399
signature verification, 460	Serial test, 181, 188
SEAL stream cipher, 213–216	Session key, 36, 494
implementation report, 222	Session key establishment, 491
patent, 222	SHA-1, see Secure Hash Algorithm (SHA-1)
test vectors, 215	Shadow, 538
Sealed authenticator, 361	Shamir's no-key protocol, 500, 535
Sealed key, 568	Shamir's threshold scheme, 526, 539
2nd-preimage resistance, 323, 325	Shared control schemes, 524–525
Secrecy, see Confidentiality	Shares, 524–528, 538
Secret broadcasting scheme, 540	SHARK block cipher, 281
Secret key, 544	Shift cipher, 239
Secret-key certificate, 588	Short-term key, 553
Secret sharing, 524–528, 538–540	Shrinking generator, 211–212
access structure, 526	implementation report, 221
authorized subset, 527	Sieving, 97
dynamic, 527	Signature, 3, 22–23, 28–30, 425–488
extendable, 526	arbitrated, 472–473
generalized, 526–528	blind, see Blind signature scheme
ideal, 527	designated confirmer, 487
information rate, 527	deterministic, 427
multi-secret threshold, 527	Diffie-Lamport, 485
perfect, 526, 527	Digital Signature Algorithm (DSA), 452-454
pre-positioned, 527	ElGamal, 454–459
ramp schemes, 539	ESIGN, 473–474
shared control schemes, 524-525	fail-stop, see Fail-stop signature scheme
threshold scheme, 525–526	Feige-Fiat-Shamir, 447–449
verifiable, 527	framework, 426–433
visual cryptography, 539	generation algorithm, 426
with disenrollment, 528	GMR, 468–471
Secure channel, 13	GQ, 450–451
Secure Hash Algorithm (SHA-1), 348	group, 488
ANSI X9.30-2 standard, 651	handwritten, 23
FIPS 180-1 standard, 654	Merkle one-time, 464–466
ISO/IEC 10118-3 standard, 647	modified-Rabin, 439–442
Secured channel, 13	Nyberg-Rueppel, 460–462
Security domain, 570	on-line/off-line, 486
Security policy, 545	Ong-Schnorr-Shamir (OSS), 482, 486
Seed, 21, 170	Rabin, 438–442
Selective forgery, 326, 432	Rabin one-time, 462–464
Self-shrinking generator, 221	randomized, 427
Self-synchronizing stream cipher, 194–195	relation to identification, 388
Semantically secure public-key encryption, 306	resolution of disputes, 30
Semi-weak keys of DES, 257	RSA, 433–438
Sender, 13	Schnorr, 459–460
Sequence	strongly equivalent, 485
block of, 180	types of attacks, 432
de Bruijn, 203	undeniable, see Undeniable signature scheme
gap of, 180	verification algorithm, 426
m-sequence, 197	with appendix, 481
periodic, 180	framework, 428–430
pn-sequence, 181	ISO/IEC 14888 standard, 648

PKCS #1, 445-447	prime modulus, 100-101, 127
with message recovery, 29	SQROOT problem, 101
framework, 430–432	Square-free factorization, 123
ISO/IEC 9796 standard, 442–444, 646,	algorithm for, 123, 132
660	Square-free integer, 137
with redundancy, 29	Square-free polynomial, 123
Signature notarization, 583	Stage
Signature space, 427	of an FSR, 202
Signature stripping, 510	of an LFSR, 195
Signed-digit representation, 627–628	Standard deviation, 51
Signed-magnitude representation, 593	Standard normal distribution, 176
Signer, 23	Standards, 645-657, 660-661
Significance level, 179	ANSI, 648–651
Signing transformation, 22	FIPS, 654–655
Simple substitution cipher, see Mono-alphabetic sub-	IEEE, 660
stitution cipher	Internet, 655–656
Simulator, 407	ISO/IEC, 645-648, 651-653
Simultaneous diophantine approximation, 121–122	PKCS, 656
algorithm for, 122	RFC, 655–656
unusually good, 121	X.509, 653
Simultaneous multiple exponentiation, 617	Station-to-station (STS) key agreement, 519, 538
Simultaneously secure bits, 115	Statistical test, 175–185, 188–189
Single-key encryption, 15	autocorrelation test, 182
Single-length MDC, 339	frequency test, 181
Single-precision integer, 593	hypothesis, 179
Singleton bound, 506	Maurer's universal statistical test, 183–185,
SKEME, 661	189
SKID2 identification protocol, 402, 421	one-sided test, 179
SKID3 identification protocol, 402, 421	poker test, 182
SKIP, 661	polynomial-time, 171
SKIPJACK block cipher, 282, 654	runs test, 182
Sliding-window exponentiation, 616	serial test, 181
Small decryption exponent in RSA, 288	significance level, 179
Small encryption exponent in RSA, 288, 291, 313	two-sided test, 180
Smart card, 387	Statistical zero-knowledge protocol, 424
ISO 10202 standard, 652	Steganography, 46
Smooth	Step-1/step-2 generator, 220
integer, 92	Stirling numbers, 53
polynomial, 112	Stirling's formula, 59
Snefru hash function, 380	Stop-and-go generator, 220
$8 \times 32$ S-boxes, 281	Stream cipher, 20–21, 191–222
Solovay-Strassen primality test, 138, 165	A5, 222
Span, 80	attacks on
Sparse linear equations, 129	correlation attack, 206, 218
conjugate gradient method, 129	inversion attack, 219
* * *	
Lanczos method, 129	linear consistency attack, 219–220
Wiedemann algorithm, 129	linear cryptanalysis, 219
Special-purpose factoring algorithm, 90	linear syndrome attack, 218
SPKM, 656, 661	lock-in, 221
Split-knowledge scheme, 525	cellular automata, 222
Splitting an integer, 89	classification, 192–195
Spread spectrum, 45	clock-controlled generator, 209–212
Square roots, 99–102	alternating step generator, 209–211
composite modulus, 101–102, 127	m-sequence cascade, 221

<i>p</i> -cycle cascade, 220 self-shrinking generator, 221	Subspace of a vector space, 80 Substitution cipher, 17–18, 238–241
shrinking generator, 211–212	homophonic, 17, 240
step-1/step-2 generator, 220	mono-alphabetic, 17, 239
stop-and-go generator, 220	affine cipher, 239
comparison with block ciphers, 192	Caesar cipher, 239
FISH, 222	shift cipher, 239
GOAL, 219	unicity distance of, 247
initial state, 193, 194	polyalphabetic, 18
keystream, 193, 194	polygram, 239
next-state function, 193	Hill cipher, 240
nonlinear combination generator, 205–208	Playfair cipher, 239
Geffe generator, 206	Substitution-permutation (SP) network, 251
multiplexer generator, 220	Summation generator, 207, 218
multispeed inner-product generator, 220	Superincreasing subset sum problem, 300
Pless generator, 218	algorithm for solving, 300
summation generator, 207	Superuser, 389
nonlinear filter generator, 208–209	Surjective function, 46, 50
knapsack generator, 209	SWIFT, 586
one-time pad, 192–193	Symmetric cryptographic system, 544
output function, 193, 194	Symmetric key, 544
PIKE, 222	compared vs. public-key, 31–32, 551
randomized stream cipher, 216	Symmetric-key certificate, 554–555, 587
RC4, 222	Symmetric-key encryption, 15–21
Rip van Winkle cipher, 216	advantages of, 31
SEAL, 213–216	block cipher, 223-282
self-synchronizing stream cipher, 194–195	definition of, 15
synchronous stream cipher, 193-194	disadvantages of, 31
Strict avalanche criterion (SAC), 277	stream cipher, 191–222
String-replacement representation, 628–629	Synchronous stream cipher, 193–194
Strong collision resistance, 324	binary additive stream cipher, 194
Strong equivalent signature schemes, 485	Syndrome decoding problem, 190, 423
Strong liar, 139	
Strong one-way hash function, 325	T
Strong prime, 149–150	Tapper, 13
algorithm for generating, 150	TEA block cipher, 282
definition of, 149, 291	TEMPEST, 45
Hellman-Bach patent, 643	Teraflop, 44
usage in RSA, 291	Terminal key, 552
Strong pseudoprime, 139	Test vectors
Strong pseudoprime test, see Miller-Rabin primal-	DES, 256
ity test	FEAL, 262
Strong witness, 139	IDEA, 265
Subexponential-time algorithm, 60	MD4, 345
Subfield, 77	MD5, 345
Subgroup, 76	MD5-MAC, 358
Subliminal channel, 485	RC5, 270
broadband, 485	RIPEMD-160, 345
narrowband, 485	SAFER, 269
Subset sum problem, 61, 117–122, 190	SHA-1, 345
meet-in-the-middle algorithm, 118	3-WAY block cipher, 281
naive algorithm, 117	Threshold cryptography, 534
superincreasing, 300	Threshold scheme, 525–526
using $L^3$ algorithm, 120	Blakley, 538

Shamir, 526, 539	off-line, 548
Ticket, 501, 570, 586	on-line, 547
Time-memory tradeoff, 236, 273	registration authority, 549
Time-variant parameter, 362, 397–400, 497	timestamp agent, 550
nonce, 397	unconditionally trusted, 39
random numbers, 398–399	TTP, see Trusted third party (TTP)
sequence numbers, 399	Turing-Kolmogorov-Chaitin complexity, 217
timestamps, 399–400	Two's complement representation, 594
Timestamp, 3, 399–400, 420, 581–582	2-adic span, 218
agent, 550	Two-bit test, 181
Toeplitz matrix, 382	Two-key triple-encryption, 235
Transaction authentication, 362	chosen-plaintext attack on, 236
Transformation, 6	known-plaintext attack on, 237
Transinformation, 57	Two-sided statistical test, 180
Transposition cipher, 18, 238	Type I error, 179
compound, 238	Type II error, 179
simple, 18, 238	
unicity distance of, 246	${f U}$
Trapdoor one-way function, 9, 26	Unbalanced RSA, 314
Trapdoor predicate, 318	Unblinding function, 475
Tree authentication, 376	Unconcealed message, 290
patent, 637	Unconditional security, see Perfect secrecy, 533
Trinomial, 154	Unconditionally trusted third party, 39
Triple encryption, 235–237, 272	Undeniable signature scheme, 476–478, 487–488
Triple-DES, 272, 651	Chaum-van Antwerpen, 476–478
ANSI X9.52 standard, 651	confirmer, 487
Triple-inner-CBC mode, 237	Unicity distance
Triple-outer-CBC mode, 237	definition of, 246
Truncated differential analysis, 271, 280	known-plaintext, 235
Trust model, 572	of a cascade cipher, 272
centralized, 573	of a mono-alphabetic substitution cipher, 247
directed graph, 575	of a transposition cipher, 246
distributed, 575	Unilateral authentication, 387, 401–402, 405, 494
hierarchy with reverse certificates, 575	Union of sets, 49
rooted chain, 573	Unique factorization domain, 81
separate domains, 573	Unit, 68, 77, 103, 114
strict hierarchical, 573	Universal classes of hash function, 376
Trusted server, 491	Universal exponent, 287
Trusted third party (TTP), 30, 36, 491, 547–550,	Universal forgery, 482
581–584	Universal one-way hash function, 377
authentication server, 549	Universal statistical test, see Maurer's universal statistical test
certificate directory, 549	UNIX passwords, 393–394
certification authority (CA), 548	Unsecured channel, 13
functionally trusted, 39	Unusually good simultaneous diophantine approx-
in-line, 547	imation, 121, 317
KDC, see Key distribution center (KDC)	Userid, 388
key access server, 549 key escrow agent, 550	Oscila, 300
	$\mathbf{V}$
key generator, 549	Validation, 3
key management facility, 549 key server, 549	Validation parameters, 462
KTC, see Key translation center (KTC)	Variance, 51
name server, 549	Vector space, 79–80
notary agent, 550	dimension of, 80
notary agent, 330	standard basis, 80

subspace of, 80  Vector-addition chains, 622–623  Verifiable secret sharing, 527, 539  Verification algorithm, 426  Verification transformation, 22  Verifier, 23, 385, 386  Vernam cipher, <i>see</i> One-time pad  Vigenère cipher, <i>see</i> Polyalphabetic substitution cipher  Visual cryptography, 539	Schnorr, 414–416 syndrome decoding problem, 423 Zero-knowledge protocol, 405–417, 421–424 auxiliary-input, 423 black-box simulation, 423 challenge, 409 completeness, 406 computational, 407 extracting secret, 406 for possession of discrete log, 422
W WAKE block cipher, 282 Weak collision resistance, 324 Weak keys of DES, 257 Weak one-way hash function, 325 Wheatstone disc, 274 Wholesale banking, 648 Wiedemann algorithm, 129 Williams' public-key encryption, 315 Witness, 135, 409 Euler, 137	parallel version, 412 perfect, 407 proof of knowledge, 406, 421, 422 proof of membership, 421 response, 409 simulator, 407 soundness, 406 statistical, 424 witness, 409 Ziv-Lempel complexity, 217 $\mathbb{Z}_p$ -operation, 82 <b>ZPP</b> , 63
Fermat, 136 strong, 139 Witness hiding protocol, 423 Witness indistinguishability, 423 Witnessing, 3 Work factor, 44 historical, 44 Worst-case running time, 58 Wyner's wire-tap channel, 535  X X.509 authentication protocol, 536 three-way, 512 two-way, 511 X.509 certificate, 587 X.509 standard, 653	
XOR, see Exclusive-or  Y Yuval's birthday attack, 369	
Z Zero-knowledge identification, 405–417, 421–424 Brickell-McCurley, 423 comparison of protocols, 416–417 constrained linear equations problem, 423 extended Fiat-Shamir, 422 Feige-Fiat-Shamir, 410–412 Fiat-Shamir (basic version), 408 Fischer-Micali-Rackoff, 422 GQ, 412–414 Ohta-Okamoto, 422 permuted kernel problem, 423	

©1997 by CRC Press, Inc. — See accompanying notice at front of chapter.