Midterm
CSE 5/7399
Computer System Security
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Instructions: Please keep all answers as concise as possible while still conveying all necessary concepts. Please show all necessary work. An extra page is provided in the event that you need more room.

1. Using the following word bank, select fill in the blank with the term most directly related to the concepts below:

Authorization	Authentication	Symmetric Key System
Cipher Text	Kerckhoff's Principle	Plain Text
Public Key System		

   (a) Symmetric Key System Can be used with a Message Authentication Code to provide Integrity to a message.

   (b) Cipher Text The scrambled version of the message in an encryption system.

   (c) Authorization The process of giving someone permission to do or have something. Limited by such technologies as firewalls, Intrusion Detection Systems, and Multilevel Security Systems

   (d) Kerckhoff's Principle The idea that a cryptosystem should be secure even if everything about the system, except the key, is public knowledge.

   (e) Public Key System Provides the ability to add a secure 'digital signature' to a message.

   (f) Plain Text The original input into an encryption system before modification to obfuscate the message.

   (g) Authentication The process of determining whether someone or something is, in fact, who or what it is declared to be.

2. Briefly describe each of the three components of the C.I.A. Triad including what each is directed at protecting:

   Solution: CIA: Confidentiality, Integrity, and Availability.
   For the Confidentiality prevent unauthorized reading of information, cryptography used for confidentiality.
   For the Integrity detect unauthorized writing information, cryptography used for integrity.
   For the Availability Data is available in a timely manner when needed. Availability is a "new" security concern. For example, denial of service(DoS) attacks.

3. A Feistel Cipher is a general format for one possible method of performing a block cipher. Describe the basic flow of a Feistel cipher being sure to include what primary mathematical operator is required to meet this format. (Be able to describe the flow. This can be a flow chart, series of algorithms, or textual description.).

   Solution: Feistel Cipher is a type of block cipher, not a specific block cipher.

   (a) Split plaintextblock into left and right halves: $P = (L_0, R_0)$.

   (b) For each round $i = 1, 2, ..., n$ compute

   $$L_i = R_{i-1}$$
   $$R_i = L_{i-1} \oplus F(R_{i-1}, K_i)$$
   Where F is round function and K_i is subkey

   (c) Now can have the Ciphertext: $C = (L_n, R_n)$

4. Compare and contrast Symmetric Key Systems vs. Public Key Systems

   Solution: A symmetric key cryptosystem uses the same key to encrypt as to decrypt.
   A public key cryptosystem uses a public key to encrypt and a private key to decrypt.

   (a) **Key Management:**
   Symmetric Key Systems: Only one key is used for both encryption and decryption. Both parties like sender and receiver need to have the same key to communicate securely.
   Public Key Systems: Two different keys are used: the public key and the private key. The public key is used for encryption and the private key is used for decryption. Everyone can know and use a user's public key, but only the user should know their private key.

   (b) **Use Cases:**
   Symmetric Key Systems: Typically used to encrypt data at rest, for example encrypting files on a hard drive. Commonly used for session encryption to establish a shared key for a single session.
   Public Key Systems: Commonly used to protect data in transit, such as during email or online transactions. Key exchange for example: Diffie-Hellman key exchange and digital signatures.

(c) **Speed and Efficiency:**
Symmetric Key Systems Usually faster than public key encryption and requires less computational resources. Encrypt large amounts of data efficiently.
Public Key Systems: It is computationally intensive and slower than symmetric key encryption. It is not suitable for directly encrypting large amounts of data. Instead, it is commonly used to encrypt symmetric keys, which are then used to encrypt data.

(d) **Security:**
Symmetric Key Systems: The main challenge is the secure distribution and management of keys. If the key is compromised, the data is compromised. The communicating parties must have a trusted way to exchange keys without eavesdropping.
Public Key Systems: Since the public key can be freely distributed and only the private key can decrypt the message, there is no need for a secure channel to exchange encryption keys. If not implemented correctly, they are vulnerable to specific attacks for example :man-in-the-middle attacks if the public key is not properly verified.

5. a. What are the three primary components of Public Key Infrastructure?

   Solution: Certificate Authority (CA), Registration Authority (RA), Digital Certificates

   b. Briefly describe one of the primary PKI Trust Models.

   Solution: One of the primary PKI Trust Models: Oligarchy.

   i. Multi-trusted CAs: In this model, instead of a single CA being universally trusted like in the strict hierarchical model, multiple independent CAs are trusted. Each of these CAs can issue, validate, and revoke certificates..
   ii. This is the approach used in modern browsers: modern web browsers and operating systems come with a set of trusted root certificates, often called a trust store.
   iii. Certificate Validation: When a user visits a secure (HTTPS) website, the website provides its SSL/TLS certificate for validation.
   iv. Browsers may have 80 or more Certificates, just to validate certificates: A trusted store may contain certificates from dozens and usually often 80 or more trusted CAs around the world.
   v. The user can decide which CAs to trust: advanced users can view and modify the trust store. This means that they can decide to trust a new CA by importing its root certificate, or they can revoke trust in an existing CA by removing its certificate.

6. Solve the following modular arithmetic problems:

$$\begin{array}{ll} 12 \bmod 9 = & -4 \bmod 9 = \\ 11^{-1} \bmod 8 = & 4^{-1} \bmod 9 = \\ & 49 \bmod 5 = \end{array}$$

Solution: (a) $12 \bmod 9 = 3$

(b) $-4 \bmod 9 = 4$

(c)

$$\because (11 \times \frac{1}{11}) \bmod 9 = 1$$
$$\because (11 \times 5 \bmod 9) = 55 \bmod 9 = 1$$
$$\therefore \frac{1}{11} \bmod 9 = 5 \bmod 9 = 5$$
$$\therefore 11^{-1} \bmod = 5$$

(d)

$$\because (4 \times \frac{1}{4}) \bmod 9 = 1$$
$$\because (4 \times 7) \bmod 9 = 28 \bmod 9 = 1$$
$$\therefore \frac{1}{4} \bmod 9 = 7 \bmod 9 = 7$$
$$\therefore 4^{-1} \bmod 9 = 7$$

(e) $49 \bmod 5 = 4$

7. Using the following word bank, select fill in the blank with the term most directly related to the Hashing concepts below:

Compression	Efficiency	One-Way
Weak Collision Resistance		Strong Collision Resistance
Avalanche Effect		Cyclic Redundancy Check

(a) One-Way Given a value (y) it is infeasible to find a corresponding value (x) such that $h(x) = y$

(b) Efficiency Should be computationally easy to compute $h(x)$ for any value of x

(c) Compression Requirement of all hash functions that the resulting output be significantly smaller than the given input

(d) Cyclic Redundancy Check Form of non-cryptographic hash function that has been improperly used as a method to secure the Wired Equivalency Protocol (WEP)

(e) Strong Collision Resistance given x and $h(x)$, infeasible to find any x and y, with x^1y such that $h(x) = h(y)$

(f) Weak Collision Resistance given x and $h(x)$, infeasible to find y^1x such that $h(y) = h(x)$

(g) Avalanche Effect a change to 1 bit of input should affect about half of output bits

8. Using a Shift Cipher with a key of 5, solve the following substitution cipher:

Ymj fsxbjw yt szrgjw knaj nx Inkknj-Mjqqrfs.

Solution:

Original	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Shift	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U

Therefore, "Ymj fsxbjw yt szrgjw knaj nx Inkknj-Mjqqrfs." $\rightarrow$ "the answer to number five is diffie-hellman."

9. During the first round of a DES encryption cycle, the 32-bits of R_0 are found to be:

$$R_0 = 00000000000000000010101001100100$$

This is ran through the expansion permutation box [E] below to generate 48-bit $E(R_0)$ Find $E(R_0)$.

Expansion Permutation (E)

32	1	2	3	4	5
4	5	6	7	8	9
8	9	10	11	12	13
12	13	14	15	16	17
16	17	18	19	20	21
20	21	22	23	24	25
24	25	26	27	28	29
28	29	30	31	32	1

Solution:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	1	0	0	1	0	0

Use the Expansion Permutation(E), can get:

32	1	2	3	4	5
0	0	0	0	0	0
4	5	6	7	8	9
0	0	0	0	0	0
8	9	10	11	12	13
0	0	0	0	0	0
12	13	14	15	16	17
0	0	0	0	0	0
16	17	18	19	20	21
0	0	0	1	0	1
20	21	22	23	24	25
0	1	0	1	0	0
24	25	26	27	28	29
0	0	1	1	0	0
28	29	30	31	32	1
0	0	1	0	0	0

$i.e.: E(R_0) =$

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0

Therefore, $E(R_0) =$ 000000000000000000000000001010101000011000010000

10. For this same iteration of DES, K_1 is found to be:

$$K_1 = 010011110110110100110101001010101111110110101011$$

Using the solution, $E(R_0)$, from the previous question, and K_1 find the 48-bit input for the S-Boxes, (B).

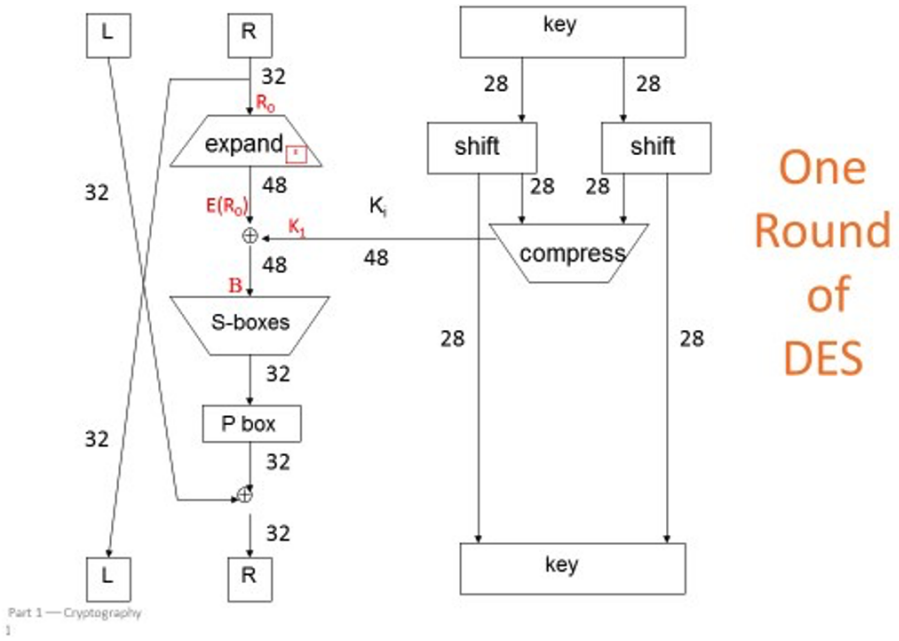
Solution:

$$\begin{aligned} E(R_0) &: 000000000000000000000000001010101000011000010000 \\ K_1 &: 010011110110110100110101001010101111110110101011 \\ \hline E(R_0) \oplus K_1 &: 010011110110110100110101001111111011111010100011 \end{aligned}$$

Therefore, the 48-bit input for the S-Boxes, (B) is:
B = 010011110110110100110101001111111011111010100011

11. Using the solution, B, from the previous question, determine the proper input and solution to S-Box, S1 below:

	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
00	1110	0100	1101	0001	0010	1111	1011	1000	0011	1010	0110	1100	0101	1001	0000	0111
01	0000	1111	0111	0100	1110	0010	1101	0001	1010	0110	1100	1011	1001	0101	0011	1000
10	0100	0001	1110	1000	1101	0110	0010	1011	1111	1100	1001	0111	0011	1010	0101	0000
11	1111	1100	1000	0010	0100	1001	0001	0111	0101	1011	0011	1110	1010	0000	0110	1101



Solution:
From the previous question, the proper input is
B_1 = 010011110110110100110101001111111011111010100011

Group the 48-bit result into sets of 6 bits:
010011 110110 110100 110101 001111 111011 111010 100011
For 010011: row = 01, col = 1001, from S-Box is : 0110
For 110110: row = 10, col = 1011, from S-Box is : 0111
For 110100: row = 10, col = 1010, from S-Box is : 1001
For 110101: row = 11, col = 1010, from S-Box is : 0011
For 001111: row = 01, col = 0111, from S-Box is : 0001
For 111011: row = 11, col = 1101, from S-Box is : 0000
For 111010: row = 10, col = 1101, from S-Box is : 1010
For 100011: row = 11, col = 0001, from S-Box is : 1100
Therefore, the solution to S-Box is:
S_1Output = 0110 0111 0011 0001 0000 1010 1100

12. Given the example below, generate a unique key pair by selecting p, q, N, e, and d (DO NOT USE ANY OF THE VALUES LISTED BELOW FOR p or q)

- Example of RSA
  - Select "large" primes p = 11, q = 3
  - Then N = pq = 33 and (p – 1)(q – 1) = 20
  - Choose e = 3 (relatively prime to 20)
  - Find d such that ed = 1 mod 20
    - We find that d = 7 works
- Public key: (N, e) = (33, 3)
- Private key: d = 7

Solution: (a) Select "large" primes $p = 17, q = 7$

(b) Then $N = pq = 119$ and $(p-1)(q-1) = 96$

(c) Choose $e = 5$(relatively prime to 96)

(d) Find d such that $ed = 1 \bmod 96 = 1$, can find $d = 77$ works. $77 \times 5 = 385 \bmod 96 = 1$

Therefore:
P = 17, q = 7, N = 119, e = 5, d = 77

Extra Work (to be turned in with Exam).