ECS 127 — Midterm 2 — Spring 2024

Instructions: The exam has this cover page then four more pages. Please write on the front side of pages only. Make your writing **clear** and **dark**—if we can't read it, it's wrong!

A reminder that you may not sit next to any partner or friend (meaning: immediately to the left, right, rear, or diagonal).

Anticipated grading (subject to change): 10 points each for problems 1–9; 40 points for problem 10, based on the number of correct responses in excess of a half.

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Name: Ai

1. Let $N = 10291 = 41 \cdot 251$ be the product of two primes.
Compute $7^{20000} \pmod{10291}$.

$\varphi(10291) = 40 \cdot 250 = 10000$, so

$7^{20000} = (7^{10000})^2 = (7^0)^2 = 1 \pmod{N}$

2. A **trapdoor permutation generator** $\mathcal{F}$ is a probabilistic algorithm that, on input of a security parameter k, outputs a pair $(\_f, \_g) \twoheadleftarrow \mathcal{F}(k)$. What's the meaning of those underscores? What's the difference between $\_f$ and f?

$\_f$ is an encoding of the function f.
$\_f$ and $\_g$ are strings, whereas f and g are functions.

3. Let $N = pq$ be the product of distinct 200-digit primes, and let $e, d \in \mathbb{Z}_N^*$ be inverses of one another in $\mathbb{Z}_{\phi(N)}^*$. Suppose you **sign directly with RSA**, signing $M \in \mathbb{Z}_N^*$ by $\sigma = M^d \pmod{N}$. Give an adversary $A^{\mathrm{Sign}_{(N,d)}(\cdot)}(N, e)$ that forges $M = 77$.

Ask the signing oracle 7, getting a response σ
Ask the signing oracle 11, getting a response σ'
Forge: $(77, \sigma \cdot \sigma' \bmod N)$

Hint: ask for the signatures of two messages, then output your forgery.

4. The **computational Diffie-Hellman assumption** (CDH) says that doing *what* is hard?

Given random group elements g^a and g^b, it is hard to compute g^{ab}.

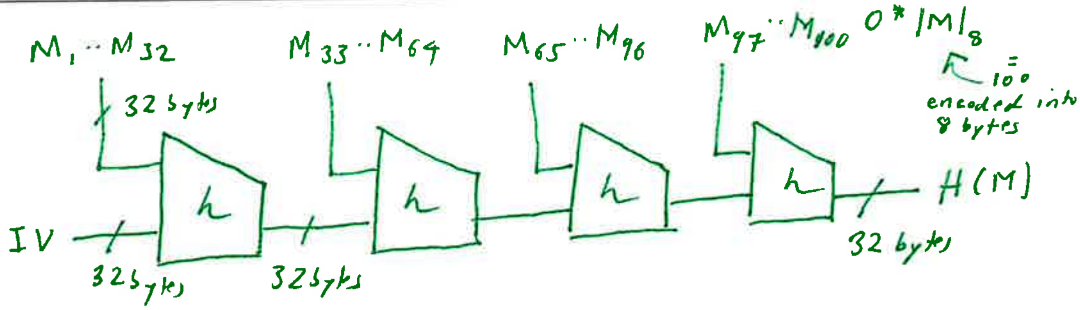
Name: Mi

5. Suppose you encrypt with a **substitution cipher** $\Sigma = (\mathcal{K}, \mathcal{E}, \mathcal{D})$. Key generator $\mathcal{K}$ outputs the description of a random permutation $\pi \twoheadleftarrow \text{Perm}(8)$ specifies a permutation on bytes. The encryption of an n-byte plaintext $M_1 \cdots M_n$ is $\mathcal{E}_\pi(M_1 \cdots M_n) = \pi(M_1) \cdots \pi(M_n)$. **Now ind-break** Σ: Specify an adversary $\mathcal{A}$ whose ind-advantage $\mathbf{Adv}^{\text{ind}}_{\Sigma}(\mathcal{A}) = \Pr[\pi \twoheadleftarrow \text{Perm}(8) : \mathcal{A}^{\mathcal{E}_\pi(\cdot)} \Rightarrow 1] - \Pr[\pi \twoheadleftarrow \text{Perm}(8) : \mathcal{A}^{\mathcal{E}_\pi(0^{|\cdot|})} \Rightarrow 1]$ is large.

Ask oracle for the encryption of AB for any distinct bytes A and B (like $A = 0^8$, $B = 1^8$). Let XY be the response, where $|X| = |Y| = 8$. If $X \neq Y$ then return 1, else return 0.

Simple adversary. Don't ask more than two queries.

6. Recall the **Merkle-Damgård construction** for making a cryptographic hash function H from a compression function h. Draw a picture that shows what happens when you hash a 100-byte message $M = M_1 M_2 \cdots M_{100}$. Assume that h that maps 64 bytes to 32 bytes. Assume that **length annotation** (required for Merkle-Damgård) is done by encoding $|M|$ in the last 8 bytes.



7. Define a blockcipher $E : \{0,1\}^{128} \times \{0,1\}^{128} \to \{0,1\}^{128}$ (make sure it *is* a blockcipher) that is **perfectly secure** (prp-advantage of 0) if the adversary asks **one** query, but is **highly insecure** (prp-advantage near 1) if the adversary asks **two** queries.

$E_K(X) = K \oplus X$

note: $= X$ is insecure with <u>one</u> query;
$= K$ is not a blockcipher

Name: Self

8. Let's use **Lamport's scheme** (lecture 9F) for a one-time, hash-based signature. Assume a hash function H that returns 32 bytes. Suppose the message you will sign is a one **byte** $M = m_1m_2m_3m_4m_5m_6m_7m_8$. The public key and secret key will be

$pk = \begin{matrix} H(A_1) & H(A_2) & \cdots & H(A_8) \\ H(B_1) & H(B_2) & \cdots & H(B_8) \end{matrix}$ where $A_1, \dots, A_8, B_1, \dots, B_8 \twoheadleftarrow \{0,1\}^{8 \cdot 32}$, say.

$sk = \begin{matrix} A_1, \cdots, A_8 \\ B_1, \cdots, B_8 \end{matrix}$

The signature of $M = 00001111$ will be

$sk = A_1 A_2 A_3 A_4 B_5 B_6 B_7 B_8$

9. **Cross out** and **fix** (reword) anything that's particularly problematic in the following. Then **explain** why you made the adjustment you did.

A **collision-resistant hash function** (also called a *collision-intractable hash function*) is a function $H: \{0,1\}^* \to \{0,1\}^n$ with the property that ~~there are no~~ nobody knows strings M and M' in the domain of H such that $M \neq M'$ yet $H(M) = H(M')$.

or: known

Explanation: By the PHP, lots of collisions exist — it's just that we don't know any. Us dumb humans, that is.

Name: Yo

10. **Darken the box** if the statement is **true**. Leave it alone otherwise.

1) ■ A symmetric encryption scheme Π that is ind\$-secure will be ind-secure.

2) ☐ A symmetric encryption scheme Π that is ind-secure will be ind\$-secure.

3) ■ A function $F\colon \mathcal{K} \times \{0,1\}^* \to \{0,1\}^{128}$ that is prf-secure will be mac-secure.

4) ☐ We know how to make a practical, provably prp-secure blockcipher.

5) ■ We know how to make a practical, provably 2^{-128}-AU hash function.

6) ■ OCB encryption is nonmalleable.

7) ☐ An encryption scheme with a key space smaller than its message space can achieve perfect ind-security.

8) ■ A MAC can be secure despite being stateless and deterministic.

9) ☐ AEAD encryption $C = \mathcal{E}(K, N, A, M)$ typically produces a ciphertext whose length increases with the length of A, the associated data.

10) ■ A Carter-Wegman MAC can authenticate a long message with only one blockcipher call.

11) ■ A prp-secure blockcipher E might have $E_K(K) = K$.

~~12) ☐ If an encryption scheme's key space is smaller than its message space, it can't achieve perfect privacy.~~ NOT GRADED BECAUS ACCIDENTAL REPETITION (OF #7)

13) ☐ ChaCha20 is an early AEAD scheme.

14) ■ There is a message M, quite long, whose CBC MAC is always a string of zeros.

15) ■ Let $E\colon \mathcal{K} \times \{0,1\}^n \to \{0,1\}^n$ be a blockcipher. For any $K \in \mathcal{K}$, the function $X \mapsto E_K(X)$ is permutation, while the function $X \mapsto X \oplus E_K(X)$ is usually not.

16) ☐ A homework showed that, experimentally, RC4 seems highly secure as a PRG.

17) ■ Adversary $\mathcal{A}$ queries a random function $f \twoheadleftarrow \{0,1\}^{128}$ at 2^{40} different points. The answers returned will probably be distinct (different from one another).

~~18) ☐ If Alice wants to go on a date with Bob, she should ignore what we did in ECS 127 and just ask him out.~~ STUDENTS VOTED 100 ■ 14 ☐ I MOST DEFINITELY VOTE ■, TOO.

Have a nice life!