Sample Quiz 1

Important Notes:

- Quiz date: 26th March (Wed), in class.
- Quiz duration: 50 minutes.
- Chapters covered: Boneh&Shoup Chapters 1-7, examinable learning points can be found in the Github repo.
- Cheat sheets: You are allowed to have **three double-sided A4-size notes**.

Question 1 (Encryption): Let $\mathcal{E} = (E, D)$ be a semantically secure cipher. Which one of the following encryption algorithms yields a semantically secure scheme? Either give an attack or provide a security proof via an explicit reduction.

(a) $E_1(k, m) = 0 \parallel E(k, m)$.

(b) $E_1(k, m) = m_0 \parallel E(k, m)$ where m_0 is the first bit of m.

Question 2 (Stream Cipher): Let G_0 and G_1 be two PRGs. Define $G(s_0, s_1) = G_0(s_0) \parallel G_1(s_1)$. Show that G is not a secure PRG if either G_0 or G_1 is not a secure PRG.
Question 3 (Block Cipher): Let F_0 and F_1 be PRFs with the same input and output spaces. Define

$$F((k_0, k_1), m) = F_0(k_0, m) \oplus F_1(k_1, m).$$

Show that F is a secure PRF if either F_0 or F_1 is a secure PRF.
Question 4 (CPA): Let $E : \mathcal{K} \times \mathcal{M} \times \mathcal{N} \to \mathcal{C}$ be an ill-formed implementation of nonce-based AES-$CBC as follows.

- Given key k and an initial nonce n that is properly generated, the first message m_0 is encrypted as $c_0 = E(k, m_0, n)$. (n is not a part of c_0.) Let $\hat{c_0}$ be the last block of c_0.
- For subsequent messages, a message m_i is encrypted as $c_i = E(k, m_i, \hat{c_{i-1}})$, where $\hat{c_{i-1}}$ is the last block of ciphertext c_{i-1}.

Show that the computational cipher based on the encryption scheme described above is not semantically secure against chosen plaintext attack.
Hint: You can pick the messages adaptively in the security game.
Question 5 (MAC): Let $H : \mathcal{K} \times \mathcal{M} \to \mathcal{T}$ be the raw CBC-MAC (without a nonce and no PRF evaluation after CBC). Show that $H'(k, m) = H(k, m \parallel \langle |m| \rangle)$ where $\langle |m| \rangle$ is a binary representation of the length of m. Show that H' is not a secure PRF (and hence, not a secure MAC).
Question 6 (Message integrity from universal hashing: Recall that PRF(UHF) composition works by combining a universal hash function H and a PRF F as $F'((k_0, k_1), m) = F(k_1, H(k_0, m))$. Show that the composition is not secure (as a PRF) if the same key is used for H and F. That is, $F'(k, m) = F(k, H(k, m))$ instead. It suffices to give particular H and F, and show a concrete attack with them.