This exam was generated for foo@bar.com

For questions with circular bubbles, you may select exactly one choice on Gradescope.

- Unselected option
- Only one selected option

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

- You can select
- multiple squares

For questions with a large box, you need to provide justification in the text box on Gradescope.

You have 170 minutes. There are 9 questions of varying credit (230 points total).

The exam is open book. You can use any resources on the Internet, including course notes, as long as you are working alone.

We will not be answering any clarifications about the exam. If there are any glaring problems with wording, we will consider dropping the question from the exam after solutions/grades are released.

Q1  MANDATORY – Honor Code  (5 points)
On your Gradescope answer sheet, read the honor code and type your name. Failure to do so will result in a grade of 0 for this exam.

We have printed the values statement you wrote in Homework 3B below:

    We did not see a values statement on your Homework 3B submission. We encourage you to take a moment and think about your core values.

We trust you will approach this exam in a way consistent with your values.

This is the end of Q1. Proceed to Q2 on your Gradescope answer sheet.
Q2  True/false  (72 points)
Each true/false is worth 2 points.

Q2.1 True or False: If a victim is logged into a session on https://bank.com/ in one tab and visits an attacker’s website in another, the attacker can run JavaScript to load a form at https://bank.com/transfer and extract the CSRF token from it.

☐ True  ☐ False

Q2.2 True or False: An on-path attacker can learn the request parameters of a GET request loaded over HTTPS.

☐ True  ☐ False

Q2.3 True or False: An on-path attacker can learn the request parameters of a GET request loaded over HTTP.

☐ True  ☐ False

Q2.4 True or False: Parameterized SQL is generally safer than forming a SQL query through string concatenation because you are less likely to be vulnerable to a SQL injection attack.

☐ True  ☐ False

Q2.5 True or False: In DNSSEC, if the root key is compromised, then no DNS records can be trusted.

☐ True  ☐ False

Q2.6 True or False: Diffie-Hellman is an effective mitigation against ROP (Return-Oriented Programming) attacks.

☐ True  ☐ False

Q2.7 True or False: Using \( H(x) = \text{SHA256}(x) \), where \( x \) is a message, forms a secure message authentication code.

☐ True  ☐ False

Q2.8 True or False: Encrypting a message with AES-CBC mode and a random IV is IND-CPA secure.

☐ True  ☐ False

Q2.9 True or False: There is no reason to use IP with UDP, since both only provide best-effort delivery.

☐ True  ☐ False

Q2.10 True or False: TLS has end-to-end security, so it is secure against an attacker who steals the private key of the server.

☐ True  ☐ False
Q2.11 True or False: If the entire Internet stopped using HTTP POST requests and only allowed HTTP GET requests, CSRF attacks would still be possible.

Q2.12 True or False: Suppose we compile a program with 512-bit canaries, and the program produces no output (so it is impossible to leak the value of the canary). It is possible to successfully write to memory located above the stack canary.

Q2.13 True or False: Suppose that in an IND-CPA game for some encryption scheme, there is an attacker who finds a way to guess the random bit correctly with probability 0.4. The scheme could still be IND-CPA.

Q2.14 True or False: There is nothing a man-in-the-middle attacker (MITM) can do to interfere with a DNSSEC query.

Q2.15 True or False: It is secure for a server to generate session tokens based only on timestamp to the nearest second, as long as every user receives a unique token.

Q2.16 True or False: Destination port randomization could be implemented to increase the security of DNS without breaking the DNS protocol shown in lecture.

Q2.17 True or False: Let $S(k, M)$ be the signing function for RSA signatures. Consider a new scheme with a signing function $S'(k, M) = [S(k, M)||r], r$ is a randomly chosen nonce and $||$ is concatenation. This scheme is IND-CPA secure.

Q2.18 True or False: If every website uses TLS and every cookie has the secure flag set, clickjacking attacks are still possible.

Q2.19 True or False: A script running on http://insecure.califlower.com can set a cookie that will be sent to http://secure.califlower.com.

Q2.20 True or False: A script running on http://insecure.califlower.com can load http://secure.califlower.com in an iframe and read data, including cookies, from that iframe.
Q2.21 True or False: A script running on http://califlower.com/insecure can load http://califlower.com/secure in an iframe and read data, including cookies, from that iframe.

Q2.22 True or False: A cookie set by califlower.com without specifying a domain will be sent to califlower.com and any subdomain of califlower.com.

Q2.23 True or False: It is possible to set a cookie for http://califlower.com that cannot be accessed by a script running on the same page.

Q2.24 True or False: A script running on http://califlower.com cannot set a cookie that will be sent to https://califlower.com because they have different origins.

Q2.25 True or False: If http://califlower.com loads http://broccoli.com in an iframe, the server of the child frame also receives all cookies that were originally sent to the server of the parent frame.

Q2.26 Suppose Harry the hacker exploits a vulnerability on http://weaksite.com to inject the following line of code: <script src="http://evil.com/script"></script>. Harry wants to hack Alice by tricking her into visiting the page and running the script to steal her cookies for weaksite.com.

   True or False: The Same-Origin Policy would prevent this attack.

Q2.27 Suppose Harry the hacker exploits a vulnerability on http://weaksite.com to inject the following line of code: <script src="http://evil.com/script"></script>. Harry wants to hack Alice by tricking her into visiting the page and running the script to steal her cookies for weaksite.com.

   True or False: Setting the Secure flag on the cookies would prevent this attack.

Q2.28 Bob is trying to access https://store.nintendo.com to buy a Switch. Suppose Eve is an on-path attacker on the same local network.

   True or False: Eve can stop Bob from accessing the Nintendo Store.
Q2.29 True or False: As long as a user uses TLS to visit a website, Tor protects anonymity even if all of their relays are malicious and colluding.

- True
- False

Q2.30 Assume you’ve set up a 3-relay Tor circuit to access some websites over HTTPS. A malicious adversary takes control of the entry relay, but the other two are honest and uncompromised. The adversary can now learn which website you are visiting.

- True
- False

Q2.31 Assume you’ve set up a 3-relay Tor circuit to access some websites over HTTPS. A malicious adversary takes control of the middle relay, but the other two are honest and uncompromised. The adversary can now learn your identity.

- True
- False

Q2.32 Assume you’ve set up a 3-relay Tor circuit to access some websites over HTTPS. A malicious adversary takes control of the exit relay, but the other two are honest and uncompromised. The adversary can now learn which website you are visiting.

- True
- False

Q2.33 True or False: With the contact tracing protocol described in class, even if a user gets diagnosed and publishes their daily tracing key, it’s impossible to track their movements for that day since their rolling identifier is re-generated every 10 minutes.

- True
- False

Q2.34 True or False: The contact tracing protocol described in class doesn’t require any centralized trust, since individuals’ phones are running the protocol.

- True
- False

Q2.35 True or False: In Bitcoin, once your transaction is successfully added to a block that lives on the longest chain, you can be guaranteed that it will never be lost.

- True
- False

Q2.36 True or False: For certificate transparency, a Merkle tree might be preferred over a block chain since adding a new certificate can be done in constant time.

- True
- False

This is the end of Q2. Proceed to Q3 on your Gradescope answer sheet. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q3  *EvanBot’s Last Creation* (15 points)

Inspired by different AES modes of operation, EvanBot creates an encryption scheme that combines two existing modes of operation and names it AES-DMO (Dual Mode Operation). Provided below is an encryption schematic of AES-DMO.

(12 points) Fill in the numbered blanks for this incomplete decryption schematic of AES-DMO. Each blank is worth 1 point.

Q3.1 Blank (1)

〇 (A) IV 〇 (B) C1 〇 (C) C2 〇 (D) C3 〇 (E) C4 〇 (F) —

Q3.2 Blank (2)

〇 (G) Enc 〇 (H) Dec 〇 (I) — 〇 (J) — 〇 (K) — 〇 (L) —

Q3.3 Blank (3)

〇 (A) IV 〇 (B) C1 〇 (C) C2 〇 (D) C3 〇 (E) C4 〇 (F) —

Q3.4 Blank (4)

〇 (G) IV 〇 (H) C1 〇 (I) C2 〇 (J) C3 〇 (K) C4 〇 (L) —
Q3.5 Blank (5)

○ (A) Enc  ○ (B) Dec  ○ (C) —  ○ (D) —  ○ (E) —  ○ (F) —

Q3.6 Blank (6)

○ (G) IV  ○ (H) C1  ○ (I) C2  ○ (J) C3  ○ (K) C4  ○ (L) —

Q3.7 Blank (7)

○ (A) IV  ○ (B) C1  ○ (C) C2  ○ (D) C3  ○ (E) C4  ○ (F) —

Q3.8 Blank (8)

○ (G) Enc  ○ (H) Dec  ○ (I) —  ○ (J) —  ○ (K) —  ○ (L) —

Q3.9 Blank (9)

○ (A) IV  ○ (B) C1  ○ (C) C2  ○ (D) C3  ○ (E) C4  ○ (F) —

Q3.10 Blank (10)

○ (G) IV  ○ (H) C1  ○ (I) C2  ○ (J) C3  ○ (K) C4  ○ (L) —

Q3.11 Blank (11)

○ (A) Enc  ○ (B) Dec  ○ (C) —  ○ (D) —  ○ (E) —  ○ (F) —

Q3.12 Blank (12)

○ (G) IV  ○ (H) C1  ○ (I) C2  ○ (J) C3  ○ (K) C4  ○ (L) —

Q3.13 (3 points) Select all true statements about AES-DMO.

☐ (A) Encryption can be parallelized
☐ (B) Decryption can be parallelized
☐ (C) AES-DMO is IND-CPA secure
☐ (D) None of the above
☐ (E) —
☐ (F) —
This is the end of Q3. Proceed to Q4 on your Gradescope answer sheet. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q4  ReenviebrmsoeC (Reasoning About Memory Safety)  (11 points)

Alice is writing a function to interleave one string with the reverse of another string. However, she is worried about memory safety issues. She wants to define some conditions that would ensure the safety of her code.

```c
void reverse_combine(char *result, char *str1, char *str2)
{
    size_t n = strlen(str1);
    int i;
    for (i = 0; i < strlen(str2); i++)
    {
        result[2*i] = str1[n-1-i];
        result[2*i+1] = str2[i];
    }
    result[2*i] = '\0';
}
```

For this question, let size(str) refer to the space allocated to str, and let len(str) refer to the length of str, not including the null terminator.

Q4.1 (3 points) Select all necessary precondition(s) for reverse_combine to ensure memory safety (but not necessarily correct functionality).

- (A) str1 and str2 are null-terminated
- (B) result != NULL
- (C) result is null-terminated
- (D) None of the above

Q4.2 len(str1) ___ len(str2)

- (G) <
- (H) <=
- (I) ==
- (J) >=
- (K) >
- (L) —

Q4.3 size(result) ___ 2*len(str2)

- (A) <
- (B) <=
- (C) ==
- (D) >=
- (E) >
- (F) —
(4 points) Fill in the following blanks so that each statement is an invariant that is guaranteed to hold at line 5, assuming the function’s precondition holds. Choose the most restrictive invariant (i.e. if both \( a < b \) and \( a \leq b \) are true, you should choose \(<\)).

Q4.4 0 ___ \( i \)

\[ \begin{array}{cccc}
(G) < & (H) \leq & (I) & (J) & (K) & (L) \\
\end{array} \]

Q4.5 \( i \) ___ len(str2)

\[ \begin{array}{cccc}
(A) < & (B) \leq & (C) & (D) & (E) & (F) \\
\end{array} \]

Q4.6 \( 2i+1 \) ___ \( 2\times\)len(str2)

\[ \begin{array}{cccc}
(G) < & (H) \leq & (I) & (J) & (K) & (L) \\
\end{array} \]

Q4.7 \( 2i+1 \) ___ \( \text{size(result)} \)

\[ \begin{array}{cccc}
(A) < & (B) \leq & (C) & (D) & (E) & (F) \\
\end{array} \]

This is the end of Q4. Proceed to Q5 on your Gradescope answer sheet. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q5  Cauliflower Smells Really Flavorful  

Califlower.com decides to defend against CSRF attacks as follows:

1. When a user logs in, califlower.com sets two 32-byte cookies session_id and csrf_token randomly with domain califlower.com.
2. When the user sends a POST request, the value of the csrf_token is embedded as one of the form fields.
3. On receiving a POST request, califlower.com checks that the value of the csrf_token cookie matches the one in the form.

Assume that the cookies don’t have the secure, HTTPOnly, or Strict flags set unless stated otherwise. Assume that no CSRF defenses besides the tokens are implemented, and that CORS is not in use (if you don’t know what that means, do not worry about it). Assume every subpart is independent.

Q5.1 (3 points) Suppose the attacker gets the client to visit their malicious website which has domain evil.com. What can they do?

☐ (A) CSRF attack against califlower.com  ☐ (D) None of the above
☐ (B) Change the user’s csrf_token cookie  ☐ (E) —
☐ (C) Learn the value of the session_id cookie  ☐ (F) —

Q5.2 (3 points) Suppose the attacker gets the client to visit their malicious website which has domain evil.califlower.com. What can they do?

☐ (G) CSRF attack against califlower.com  ☐ (J) None of the above
☐ (H) Change the user’s csrf_token cookie  ☐ (K) —
☐ (I) Learn the value of the session_id cookie  ☐ (L) —

Q5.3 (3 points) Suppose the attacker gets the client to visit a page on the website xss.califlower.com that contains a stored XSS vulnerability (the website xss.califlower.com is not controlled by the attacker). What can they do?

☐ (A) CSRF attack against califlower.com  ☐ (D) None of the above
☐ (B) Change the user’s csrf_token cookie  ☐ (E) —
☐ (C) Learn the value of the session_id cookie  ☐ (F) —

Q5.4 (3 points) Suppose the csrf_token and session_id cookies have the HTTPOnly flag set. Suppose the attacker gets the client to visit a page on the website xss.califlower.com (the website xss.califlower.com is not controlled by the attacker) that contains a stored XSS vulnerability. What can they do?

☐ (G) CSRF attack against califlower.com  ☐ (J) None of the above
☐ (H) Change the user’s csrf_token cookie  ☐ (K) —
☐ (I) Learn the value of the session_id cookie  ☐ (L) —
Q5.5 (3 points) Suppose the attacker is on-path and observes the user make a POST request over HTTP to califlower.com. What can they do?

☐ (A) CSRF attack against califlower.com  ☐ (D) None of the above
☐ (B) Change the user’s csrf_token cookie  ☐ (E) ——
☐ (C) Learn the value of the session_id cookie  ☐ (F) ——

Q5.6 (3 points) Suppose the attacker is a MITM and observes the user make a POST request over HTTPS to califlower.com. What can they do?

☐ (G) CSRF attack against califlower.com  ☐ (J) None of the above
☐ (H) Change the user’s csrf_token cookie  ☐ (K) ——
☐ (I) Learn the value of the session_id cookie  ☐ (L) ——

Q5.7 (5 points) Suppose the attacker is a MITM. The victim uses HTTP and is logged into califlower.com but will not visit califlower.com at all. Describe how this attacker can successfully perform a CSRF attack against califlower.com when the user makes a single request to any website. (Hint: Remember a MITM can modify a webpage over HTTP since there are no integrity checks.)

This is the end of Q5. Proceed to Q6 on your Gradescope answer sheet. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q6  I Knew UDP Was Trouble  (22 points)

In the following diagram, Alison is connected to the network through her local router, which is connected
to the local DNS resolver, which in turn uses iterative queries to resolve domains. Ports and the random
UDP ID numbers are 16 bits, and DNS queries use 53 as both the source and destination ports. Mallory
is an on-path attacker, while Eve is an off-path attacker. cs161.org, .org, .com, and the root domain
support DNSSEC, but taylorswift.com does not. DNS caches always start empty. Each subpart is
independent.

Q6.1 (5 points) Which of the following entities, if malicious, could poison Alison’s DNS resolver’s cache
for taylorswift.com?
(A) Mallory
(B) Name server for .
(C) Name server for .com
(D) Name server for .org
(E) Name server for taylorswift.com
(F) None of the above

Q6.2 (5 points) Which of the following entities, if malicious, could poison Alison’s DNS resolver’s cache
for cs161.org?
(G) Mallory
(H) Name server for .
(I) Name server for .com
(J) Name server for .org
(K) Name server for taylorswift.com
(L) None of the above
Q6.3 (4 points) Which of the following actions would be effective in preventing Mallory from having a non-negligible probability of being able to poison the cache for taylorswift.com?

☐ (A) Using TLS for all DNS queries
☐ (B) Using DNSSEC for taylorswift.com
☐ (C) Using TCP instead of UDP for the DNS query
☐ (D) Source port randomization
☐ (E) None of the above
☐ (F) —

Q6.4 (4 points) Which of the following actions would be effective in preventing Eve from having a non-negligible probability of being able to poison the cache for taylorswift.com?

☐ (G) Using TLS for all DNS queries
☐ (H) Using DNSSEC for taylorswift.com
☐ (I) Using TCP instead of UDP for the DNS query
☐ (J) Source port randomization
☐ (K) None of the above
☐ (L) —

Q6.5 (4 points) Which of the following actions would be effective in preventing a malicious .com name server from having a non-negligible probability of being able to poison the cache for taylorswift.com?

☐ (A) Using TLS for all DNS queries
☐ (B) Using DNSSEC for taylorswift.com
☐ (C) Using TCP instead of UDP for the DNS query
☐ (D) Source port randomization
☐ (E) None of the above
☐ (F) —

This is the end of Q6. Proceed to Q7 on your Gradescope answer sheet. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q7  **Pairing an IOT Device**

Alice wishes to pair her new IoT device and her laptop by having them exchange a symmetric key $k$. The devices will later use $k$ to encrypt plaintext messages and send the ciphertexts to each other. Assume that there is a MITM on the network between the IoT device and the laptop. To defend against the MITM, Alice is considering the security of different pairing protocols. For each scenario below, select all true statements.

The “old key” refers to a symmetric key from some previous pairing. $\text{Enc}(PK; m)$ refers to public-key encryption of $m$ with $PK$. Each subpart is independent.

Q7.1 (4 points) The IoT device chooses $k$ randomly and sends it to the laptop unencrypted over the network.
- (A) MITM can decrypt the messages from the IoT device to the laptop
- (B) MITM can decrypt the messages from the laptop to the IoT device
- (C) At least one of the devices could accept an attacker’s key that was not an old key
- (D) MITM can make at least one of the devices to accept an old key
- (E) None of the above

Q7.2 (4 points) The IoT device sends a message to the laptop asking for its public key $PK$. The laptop sends $PK$ to the IoT device. The IoT device chooses $k$ randomly and sends $\text{Enc}(PK; k)$ to the laptop.
- (G) MITM can decrypt the messages from the IoT device to the laptop
- (H) MITM can decrypt the messages from the laptop to the IoT device
- (I) At least one of the devices could accept an attacker’s key that was not an old key
- (J) MITM can make at least one of the devices to accept an old key
- (K) None of the above

Q7.3 (4 points) Alice manually enters the publicly-known $PK$ of the laptop into the IoT device. The IoT device chooses $k$ randomly and sends $\text{Enc}(PK; k)$ to the laptop.
- (A) MITM can decrypt the messages from the IoT device to the laptop
- (B) MITM can decrypt the messages from the laptop to the IoT device
- (C) At least one of the devices could accept an attacker’s key that was not an old key
- (D) MITM can make at least one of the devices to accept an old key
- (E) None of the above

- (F) —
Q7.4 (4 points) Alice manually enters the publicly-known PK of the laptop into the IoT device, and the publicly-known verification key of the IoT device into the laptop. The IoT device chooses $k$ randomly, computes $Enc(PK, k)$, and sends this ciphertext to the laptop along with a signature of the ciphertext from the IoT device. The laptop verifies the signature and rejects the key if the signature fails.

☐ (G) MITM can decrypt the messages from the IoT device to the laptop
☐ (H) MITM can decrypt the messages from the laptop to the IoT device
☐ (I) At least one of the devices could accept an attacker’s key that was not an old key
☐ (J) MITM can make at least one of the devices to accept an old key
☐ (K) None of the above

Q7.5 (4 points) The IoT device and the laptop run Diffie-Hellman key exchange to agree on the symmetric key.

☐ (A) MITM can decrypt the messages from the IoT device to the laptop
☐ (B) MITM can decrypt the messages from the laptop to the IoT device
☐ (C) At least one of the devices could accept an attacker’s key that was not an old key
☐ (D) MITM can make at least one of the devices to accept an old key
☐ (E) None of the above

Q7.6 (4 points) Alice manually enters the verification key of the IoT device into the laptop. The IoT device and the laptop run Diffie-Hellman key exchange to agree on $k$. The IoT device signs its DH public key and sends it with a signature to the laptop as part of this exchange. The laptop verifies the signature and rejects the key if the signature fails.

☐ (G) MITM can decrypt the messages from the IoT device to the laptop
☐ (H) MITM can decrypt the messages from the laptop to the IoT device
☐ (I) At least one of the devices could accept an attacker’s key that was not an old key
☐ (J) MITM can make at least one of the devices to accept an old key
☐ (K) None of the above

Q7.7 (4 points) The IoT device and the laptop run Diffie-Hellman key exchange to agree on $k$. Additionally, the IoT device displays the hash of the resulting symmetric key, which Alice inputs into the laptop. The laptop hashes its copy of the symmetric key and rejects the key if the hashes don't match.

☐ (A) MITM can decrypt the messages from the IoT device to the laptop
☐ (B) MITM can decrypt the messages from the laptop to the IoT device
☐ (C) At least one of the devices could accept an attacker’s key that was not an old key
☐ (D) MITM can make at least one of the devices to accept an old key
☐ (E) None of the above

This is the end of Q7. Proceed to Q8 on your Gradescope answer sheet. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q8 SQL Enumeration (21 points)

Alice runs a computing cluster. When a user wants to execute some job $job$, they visit:

https://alice.com/execute?job=$job

Alice’s server locally stores a SQL table named dns:

<table>
<thead>
<tr>
<th>IP</th>
<th>hostname</th>
<th>jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.120.2.4</td>
<td>gpus.alice.com</td>
<td>matrix-multiplication</td>
</tr>
<tr>
<td>10.120.2.75</td>
<td>cpu1.alice.com</td>
<td>matrix-addition</td>
</tr>
<tr>
<td>10.120.2.6</td>
<td>cpu2.alice.com</td>
<td>matrix-addition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Upon receiving a request, Alice’s server makes the following SQL query:

SELECT IP, hostname FROM dns WHERE jobs='$$job$$' ORDER BY RAND() LIMIT 1

where $job$ is copied from the request parameter. This SQL query finds all hosts in dns whose jobs field equals the string $job$, and randomly returns one of them. If successful, the job is sent to the specified IP, and the following webpage is returned:

Successfully launched job on hostname!

Otherwise an error code is returned. hostname is copied from the SQL query result.

Q8.1 (3 points) What type of attack is the server vulnerable to?

- (A) SQL injection
- (B) ROP attack
- (C) CSRF attack
- (D) Path traversal attack
- (E) None of the above

Q8.2 (5 points) Mallory wants to learn all of the hostnames in the dns table. She will repeatedly load https://alice.com/execute?job=$job with a specially chosen value for $job$ (the same value every time). Specify a value she could use so that with enough repetitions, she will learn all of the hostnames.

- (G) —
- (H) —
- (I) —
- (J) —
- (K) —
- (L) —
Q8.3  (5 points) Alice catches on to Mallory’s exploit and decides to escape some special characters. In particular, the characters ' ( ) < > are all escaped with a backslash (i.e., \) before the query is executed.

**True or False:** Despite the escaping, it is still possible to choose a value for $job$ that meets the requirement of the previous part. If you choose true, show such a value; if you choose false, explain why it’s no longer possible.

- (A) True  
- (B) False  
- (C) —  
- (D) —  
- (E) —  
- (F) —

Q8.4  (3 points) Instead of escaping, Alice modifies the server to check that $job$ contains only letters (a-z), dashes (-), quotes ('), and/or spaces (.). If $job$ contains any other character, it rejects the request without making any SQL queries. Assume that the server’s code includes the entire response from the SQL query in the web page for debugging purposes.

**True or False:** It is possible to choose a value for $job$ that will let Mallory learn all hostnames that can handle a matrix-addition job in a single visit to the web page. If you choose true, show such a value; if you choose false, explain why it’s no longer possible. *(Hint: -- starts a SQL comment. Assume that it does not need to be preceded or followed by a space.)*

- (G) True  
- (H) False  
- (I) —  
- (J) —  
- (K) —  
- (L) —
Q8.5 (5 points) Instead of the checks in the previous part, Alice implements a simple filter on the value of $job$:

```python
def sanitize(job):
    job = job.replace('−−', '')  # Deletes all occurrences of −−
    job = job.replace(';', '')  # Deletes all occurrences of ;
    return job
```

After calling `sanitize`, she checks that the result contains only letters (a-z), dashes (-), quotes ('), and spaces ( ), then uses it in the SQL query.

**True or False:** It is still possible to choose a value for $job$ that will let Mallory learn all hostnames that can handle a matrix-addition job in a single visit to the web page. If you choose true, show such a value; if you choose false, explain why it’s no longer possible.

- (A) True
- (B) False
- (C) —
- (D) —
- (E) —
- (F) —

**This is the end of Q8. Proceed to Q9 on your Gradescope answer sheet.** If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Q9  Memory Safe and Sound  (33 points)

Taylor Swift is hacking into Big Machine Records to retrieve the copies of her masters. She has a 39-byte long string of shellcode that will grant her access to their system. After some GDB debugging, she discovers that at line 10 of `main`, the RIP of `main` is stored at address 0xbfaecf84.

Assume a 32-bit x86 architecture with null-terminated stack canaries, but no W’X bit or ASLR. Local variables are pushed onto the stack in the order that they are declared, and there are no exception handlers or saved registers. Recall that x86 stores 32-bit words in little-endian format, meaning that the least significant byte is stored first in memory (at the lowest/smallest address), and the most significant byte is stored last.

```c
void theOtherSideOfThe(int **this) {
    char better_than[40]; // And I don’t know how it
    gets(better_than + **this);
}

int main() {
    int fearless = 0; // Base 10 (Decimal)
    int deluxe = 0x30415278; // Base 16 (Hex)
    char door[8];

    fgets(door, 5, stdin); // It’s safe if we use fgets, right?
    theOtherSideOfThe(door);

    return 0;
}
```

(5 points) Fill in the numbered blanks for this incomplete stack diagram. Each box in the diagram represents 4 bytes. Each blank is worth 1 point.
Q9.1 Blank (1)

- (A) canary
- (B) fearless
- (C) deluxe
- (D) &deluxe
- (E) &door
- (F) door

Q9.2 Blank (2)

- (G) canary
- (H) fearless
- (I) deluxe
- (J) &deluxe
- (K) &door
- (L) door

Q9.3 Blank (3)

- (A) canary
- (B) fearless
- (C) deluxe
- (D) &deluxe
- (E) &door
- (F) door

Q9.4 Blank (4)

- (G) canary
- (H) fearless
- (I) deluxe
- (J) &deluxe
- (K) &door
- (L) door

Q9.5 Blank (5)

- (A) canary
- (B) fearless
- (C) deluxe
- (D) &deluxe
- (E) &door
- (F) door

Q9.6 (5 points) What type of vulnerability(ies) are present in this code?

- (G) Buffer overflow
- (H) Off-by-one
- (I) Integer overflow
- (J) Format string vulnerability
- (K) Race condition
- (L) None of the above

Q9.7 (4 points) In which lines do the vulnerability(ies) in this code occur?

- (A) Line 2
- (B) Line 3
- (C) Line 9
- (D) Line 11
- (E) None of the above
- (F) ___
Q9.8 (12 points) What should Taylor enter to `fgets()` on line 11?

☐ (G) —  ☐ (H) —  ☐ (I) —  ☐ (J) —  ☐ (K) —  ☐ (L) —

Q9.9 (7 points) What should Taylor input into the `gets()` on line 3 to execute the shellcode? Use Python syntax. Assume that `SHELLCODE` holds the bytes of her shellcode, `NOP` holds the code for a one-byte no-op instruction, and `GARBAGE` represents an arbitrary byte whose value does not matter. You can write constants using hex (e.g., 0xFF or 0xA02200FC). For instance, 2*NOP + 4*GARBAGE + SHELLCODE would represent two no-op bytes, followed by four irrelevant bytes, followed by her 39-byte shellcode.

☐ (A) —  ☐ (B) —  ☐ (C) —  ☐ (D) —  ☐ (E) —  ☐ (F) —

This is the end of Q9. You have reached the end of the exam. If you are finished with the exam and are ready to submit your answer sheet, please follow the submission protocol.
Selected C Manual Pages

cchar *gets(char *s);

gets() reads a line from stdin into the buffer pointed to by s until either a terminating newline or EOF, which it replaces with a null byte ('\0').

char *fgets(char *s, int size, FILE *stream);

fgets() reads in at most one less than size characters from stream and stores them into the buffer pointed to by s. Reading stops after an EOF or a newline. If a newline is read, it is stored into the buffer. A terminating null byte ('\0') is stored after the last character in the buffer.
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2. Verify that your answers are saved in the PDF.

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