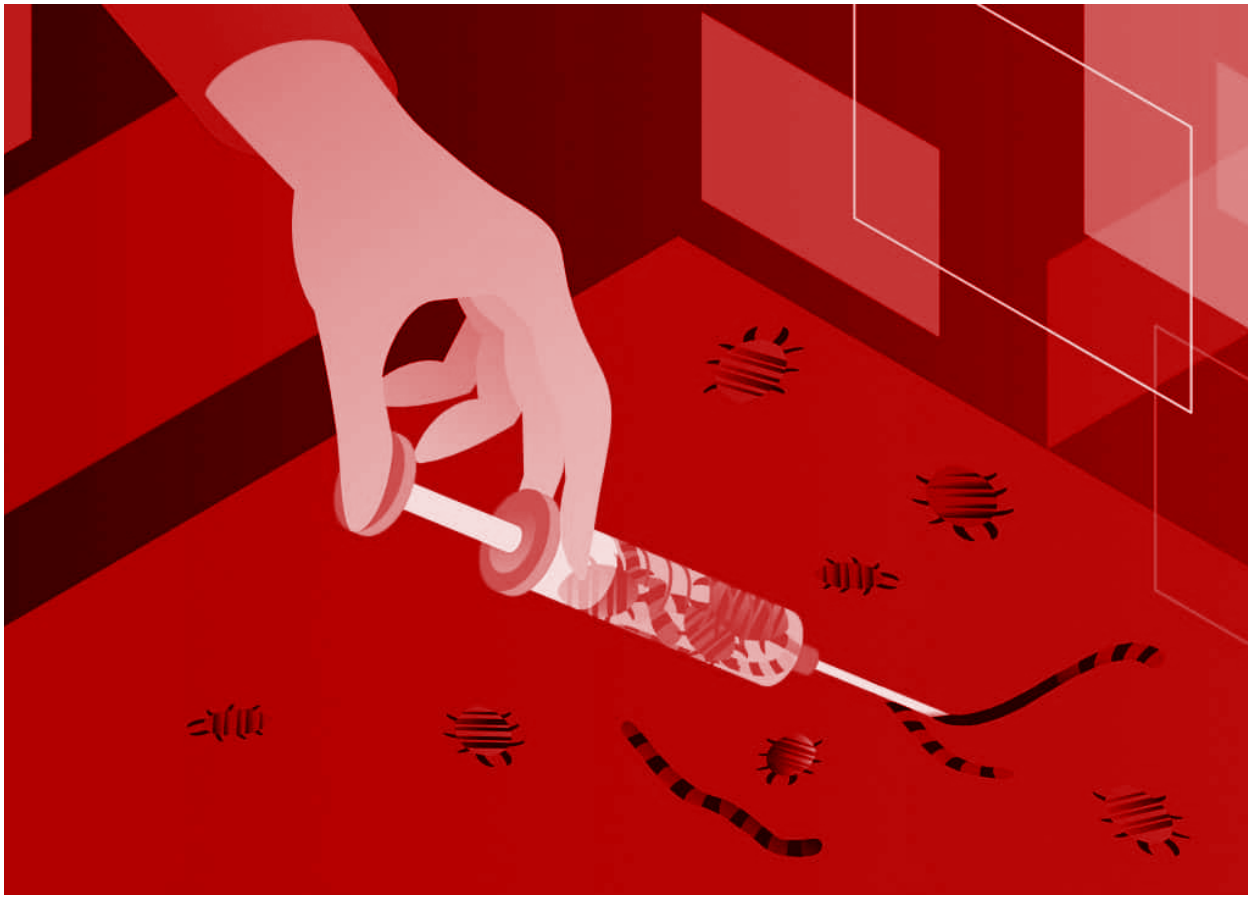
20/03/2023

ADAM LOGAN



Appointment Hack The Box Report

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Appointment

1.1 Executive Summary

This paper has shown the application is vulnerable to a blind SQL injection (SQLi) [4], by using the NIST penetration testing methodology [9]. This paper demonstrates a malicious actor can gain administrator access through this vulnerability, which is caused by low coding standards alongside misconfiguration.

The impact on security of this is enormous, as a malicious actor will have unfettered access to the application. The integrity, one of the core principles of the CIA (Confidentiality, Integrity and Availability) triad, has been violated by this vulnerability.

Therefore, the application is not safe to ship, although the cost to resolve this threat is low, as shown in the code rewrite, [1.8.2] that has occurred. This cannot be said for the cost of prevention, as this paper recommends, a change in both the way projects are managed and how the application is developed. The recommendations are to integrate DevSecOps into projects and to carry out test-driven development (TDD) [12].

1.2 Testing Performed

The NIST penetration test methodology was used to locate vulnerabilities, [9] within the application. This consists of four stages: planning [1.8.1.1], discovery [1.8.1.2], attack [1.8.1.3] and reporting. Within this section only, the discovery and attack stages will be detailed.

Within the discovery stage, it was revealed, using `nmap`, that an Apache HTTP server was running on the IP address [1.8.1.2.1]. `gobuster` [1.8.1.2.2] was then used to examine the file structure of the application, where nothing of note was found. The IP is visited within a web browser where `wappalyzer` is used to further identify the technologies used [1.8.1.2.3].

Within the attack stage, default login details [1.8.1.3.1] were tested, which all failed. After this, ‘test statements’ [1.8.1.3.2][1.8.1.3.3] were used to check for a SQLi, in which a blind SQLi was found. Then a simple SQLi was performed, which succeeded in logging into the application [1.8.1.3.4]. Another SQLi was performed to test if administrator access could be gained, which was successful [1.8.1.3.5]

The results of the testing can be viewed in section 1.8.1.

1.3 Vulnerabilities Detected

The main vulnerability within this application is lack of input sanitisation, which leads to SQLi. The risk of this cannot be understated as a malicious actor can bypass the password mechanism and alter the database, which breaches the 'integrity' pillar of the CIA triad. The severity of an SQLi can be seen through the attack on Heartland Payment Systems [4].

Malicious actors do not, necessarily, have to gain access to an administrator account to breach the integrity of the system as a 'DROP table' command can be injected. However, the malicious actor would need to have some knowledge of the database to do this.

Although a MariaDB database is used currently, if the application migrates to Microsoft SQL, OS commands can be executed through SQL statements [3][13], if the functionality to do so is enabled. As demonstrated here and in section 1.4, configuration is a low-cost solution to many vulnerabilities.

As injection is a common exploit, being third in OWASP 2021 top 10 list [6], there are many readily available exploits [11] which further highlights the risk.

1.4 Mitigation Techniques

A low-cost technique is to change the default configuration [1]. By having a more inconspicuous administrator username, malicious actors are less likely to 'guess' the correct username. A brute force attack will negate this benefit, although protections can be put in place for this, such as timeouts.

In addition, the principle of least privilege should be applied, as if a malicious actor gains access to an account the damage they can do is limited [1] [7], unless privilege escalation occurs.

Another recommendation is to use Object-Relational Mapping (ORM), which protects against SQLi as developers don't write SQL statements directly [4]. Although it is possible to override ORM with custom SQL statements which negates this benefit.

A potentially high-cost technique is to use a Web Application Firewall (WAF) to filter through requests and reject potential SQLis [8]. This would prevent the SQLi used in 1.2 but does not guarantee complete protection [10]. There are both paid and open source WAFs available and therefore the cost of this protection varies.

By implementing Multi-Factor Authentication (MFA) into the login system, a malicious actor will need to bypass more than just the password. This high-cost technique has its disadvantages as it is still possible to bypass the other authentication methods, such as with the SIM swap fraud [2].

The recommendation of this paper is to incorporate all the above security techniques to achieve defence in depth [4], this will reduce the threat as multiple security protocols will need to fail for an attack to succeed.

1.5 Actions Taken

A code rewrite [1.8.2] was undertaken, which included adding input sanitisation, parameterised statements [4]|[15] and stored procedures. Input sanitisation was achieved by creating a blacklist of common characters used in SQLis and by using character escaping functions [14]. A reduction in threat is achieved as the user input is not only limited in the control characters that are valid, but also the user input is treated as input by the database driver [4].

These techniques should be used in conjunction [1.8.2.4] according to the defence in depth [4] strategy.

1.6 Preventative Measures

A prevention technique is to integrate security into the software development lifecycle (SDLC) by adopting the DevSecOps model [12][5]. This keeps security in the forefront of project managers minds, which reduces the likelihood of future vulnerabilities.

A TDD model, used in conjunction with DevSecOps, will also reduce the threat level [12], as code will be developed to pass the tests and therefore would fail when an SQLi test is presented. The vulnerability would then be closed immediately, rather than being found later in the SDLC. A disadvantage with this approach is that development time is increased, resulting in this being a higher cost technique.

1.7 Conclusion

As detailed within this report: input sanitisation, parameterised statements and changes to the configuration file should all occur to achieve defence in depth [4].

A weakness in the report is the inability to view the exact privileges that belong to the ‘admin’ account, and therefore the damage, if a malicious user gained access to this account, could not be accurately assessed. Another limitation of the report is that the recommendations made do not make the application immune to SQLi but only more resistant.

To assist prevention of vulnerabilities it is recommended that the operational model should transition towards a DevSecOps approach along with the development model moving towards TDD.

1.8 Appendices

1.8.1 Penetration Testing

1.8.1.1 Planning

The expectation of this testing is that a SQLi vulnerability will be located, within the login page of the application. This will be the main focus of the testing, but general reconnaissance will be done on the whole application.

An attempt to discover the technologies used within the application will be made. Following this the file structure will be explored to check for hidden directories.

Depending on the information provided in the previous steps, the default configuration of the technologies will be researched for any potential vulnerabilities. As a SQLi vulnerability is expected error messages will be examined to extract any relevant information. Failing this a 'sleep' command will be used to check for a successful injection before an attempt to login is made.

Then an actual attempt will be made to login, first with a non-administrator account. The final step is to gain administrator access, by attempting to log into an administrator account.

1.8.1.2 Discovery

1.8.1.2.1 nmap

```
┌─[eu-dedicated-151-dhcp]─[10.10.14.5]─[adamlog@htb-t24chnyuep]─[~]
└──╼ [★]$ nmap -sV -sC -oA appointment 10.129.228.210
Starting Nmap 7.92 ( https://nmap.org ) at 2023-03-12 16:01 GMT
Nmap scan report for 10.129.228.210
Host is up (0.024s latency).
Not shown: 999 closed tcp ports (conn-refused)
PORT   STATE SERVICE VERSION
80/tcp open  http    Apache httpd 2.4.38 ((Debian))
|_http-title: Login
|_http-server-header: Apache/2.4.38 (Debian)

Service detection performed. Please report any incorrect results at https://nmap.org/submit/ .
Nmap done: 1 IP address (1 host up) scanned in 8.89 seconds
```

Figure 1.8.1.2.1.1: The results of the `nmap` *scan in the terminal*

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE nmaprun>
<?xml-stylesheet href="file:///usr/bin/../share/nmap/nmap.xsl" type="text/xsl"?>

<!-- Nmap 7.92 scan initiated Sun Mar 12 16:01:44 2023 as: nmap -sV -sC -oA appointment 10.129.228.210 -->
<nmaprun scanner="nmap" args="nmap -sV -sC -oA appointment 10.129.228.210" start="1678636904" startstr="Sun Mar 12 16:01:44 2023" version="7.92" xmloutputversion="1.05">
    <scaninfo type="connect" protocol="tcp" numservices="1000" services="..."/>
    <verbose level="0"/>
    <debugging level="0"/>
    <hosthint>
        <status state="up" reason="unknown-response" reason_ttl="0"/>
        <address addr="10.129.228.210" addrtype="ipv4"/>
        <hostnames></hostnames>
    </hosthint>

    <host starttime="1678636905" endtime="1678636913"><status state="up" reason="syn-ack" reason_ttl="0"/>
        <address addr="10.129.228.210" addrtype="ipv4"/>
        <hostnames></hostnames>

        <ports>
            <extraports state="closed" count="999">
                <extrareasons reason="conn-refused" count="999" proto="tcp" ports="..."/>
            </extraports>

            <port protocol="tcp" portid="80">
                <state state="open" reason="syn-ack" reason_ttl="0"/>
                <service name="http" product="Apache httpd" version="2.4.38" extrainfo="(Debian)" method="probed" conf="10">
                    <cpe>cpe:/a:apache:http_server:2.4.38</cpe>
                </service>

                <script id="http-title" output="Login">
                    <elem key="title">Login</elem>
                </script>

                <script id="http-server-header" output="Apache/2.4.38 (Debian)">
                    <elem>Apache/2.4.38 (Debian)</elem>
                </script>
            </port>
        </ports>

        <times srtt="23602" rttvar="668" to="100000"/>
    </host>

    <runstats>
        <finished time="1678636913" timestr="Sun Mar 12 16:01:53 2023" summary="..." elapsed="8.89" exit="success"/><hosts up="1" down="0" total="1"/>
    </runstats>
</nmaprun>
```

Figure 1.8.1.2.1.2: The results of the `nmap` *scan as an XML file, note that the attributes* `services`, `ports` *and* `summary` *have been replaced with '...', for the entire file to fit into the report*

1.8.1.2.2 gobuster

```
===============================================================
Gobuster v3.1.0
by OJ Reeves (@TheColonial) & Christian Mehlmauer (@firefart)
===============================================================
[+] Url:                     http://10.129.228.210
[+] Method:                  GET
[+] Threads:                 10
[+] Wordlist:                directory-list-2.3-medium.txt
[+] Negative Status codes:   404
[+] User Agent:              gobuster/3.1.0
[+] Timeout:                 10s
===============================================================
2023/03/16 15:35:27 Starting gobuster in directory enumeration mode
===============================================================

/images           (Status: 301) [Size: 317] [--> http://10.129.228.210/images/]

/css              (Status: 301) [Size: 314] [--> http://10.129.228.210/css/]

/js               (Status: 301) [Size: 313] [--> http://10.129.228.210/js/]

/vendor           (Status: 301) [Size: 317] [--> http://10.129.228.210/vendor/]

/fonts            (Status: 301) [Size: 316] [--> http://10.129.228.210/fonts/]

/server-status    (Status: 403) [Size: 279]
===============================================================
2023/03/16 15:40:02 Finished
===============================================================
```

Figure 1.8.1.2.2.1: The output of `gobuster` *using the wordlist* `directory-list-2.3-medium.txt`

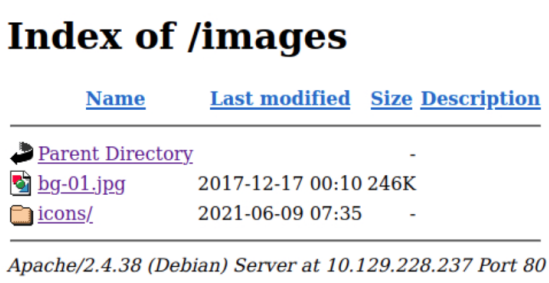

Figure 1.8.1.2.2.2: When `/images` *is visited within the browser*

Figure 1.8.1.2.2.3: When `/css` *is visited within the browser*

Index of /js

Name	Last modified	Size	Description
Parent Directory		-	
main.js	2017-12-16 23:30	2.3K	

Apache/2.4.38 (Debian) Server at 10.129.228.237 Port 80

Figure 1.8.1.2.2.4: When `/js` *is visited within the browser*

Index of /vendor

Name	Last modified	Size	Description
Parent Directory		-	
animate/	2021-06-09 07:35	-	
animsition/	2021-06-09 07:35	-	
bootstrap/	2021-06-09 07:35	-	
countdowntime/	2021-06-09 07:35	-	
css-hamburgers/	2021-06-09 07:35	-	
daterangepicker/	2021-06-09 07:35	-	
jquery/	2021-06-09 07:35	-	
perfect-scrollbar/	2021-06-09 07:35	-	
select2/	2021-06-09 07:35	-	

Apache/2.4.38 (Debian) Server at 10.129.228.237 Port 80

Figure 1.8.1.2.2.5: When `/vendor` *is visited within the browser*

Index of /fonts

Name	Last modified	Size	Description
Parent Directory		-	
font-awesome-4.7.0/	2021-06-09 07:35	-	
iconic/	2021-06-09 07:35	-	
poppins/	2021-06-09 07:35	-	

Apache/2.4.38 (Debian) Server at 10.129.228.237 Port 80

Figure 1.8.1.2.2.6: When `/fonts` *is visited within the browser*

Forbidden

You don't have permission to access this resource.

Apache/2.4.38 (Debian) Server at 10.129.228.237 Port 80

Figure 1.8.1.2.2.7: When `/server-status` *is visited within the browser*

1.8.1.2.3 Wappalyzer

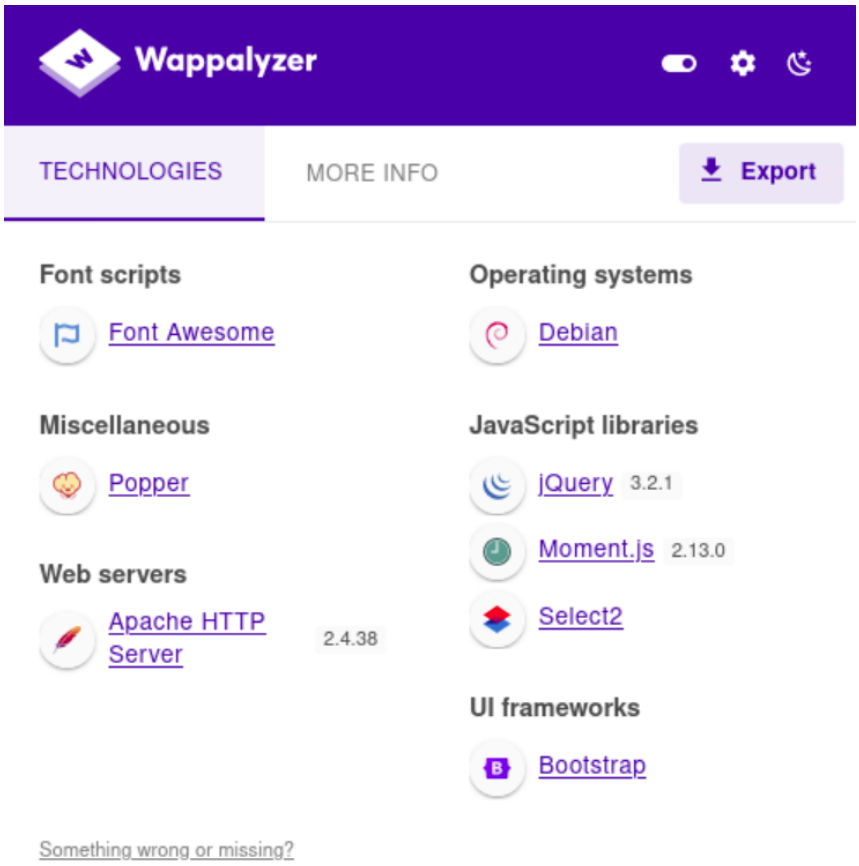

Figure: 1.8.1.2.3.1: A screenshot of `wappalyzer` *used when the IP address is visited on a browser*

URL	Font scripts	Miscellaneous	Web servers	Operating systems	JavaScript libraries	UI frameworks
http://10.129.228.210	Font Awesome	Popper	Apache HTTP Server	Debian	jQuery	Bootstrap
					Moment.js	
					Select2	

Figure 1.8.1.2.3.2: The table that is produced by `wappalyzer` *when it is exported*

1.8.1.3 Attack

1.8.1.3.1 Default Credentials

```
admin:password
admin:admin
root:password
root:root
administrator:password
administrator:administrator
```

Figure 1.8.1.3.1.1: The common administrator login details that were attempted

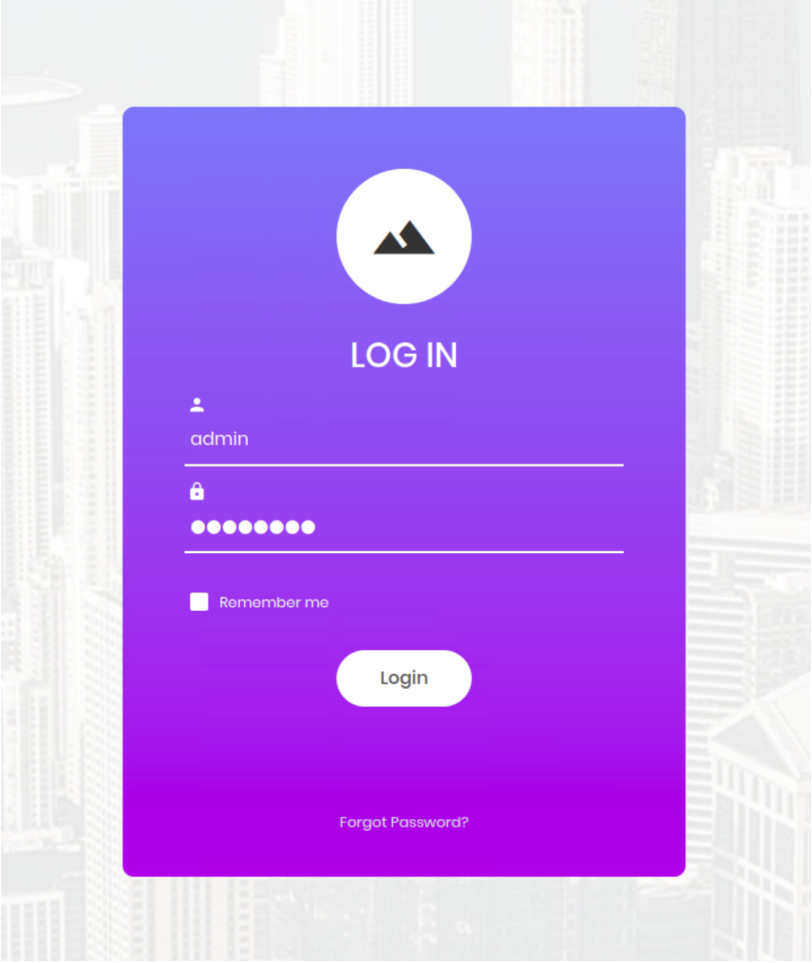

Figure 1.8.1.3.1.2: The attempt to login using admin:password

1.8.1.3.2 Checking error messages

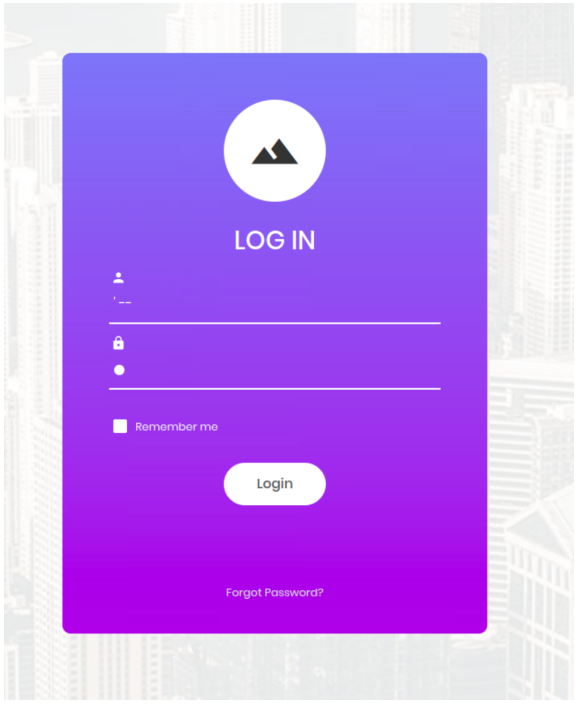

Figure 1.8.1.3.2.1: Attempts to inject a MariaDB comment character

1.8.1.3.3 Using Sleep

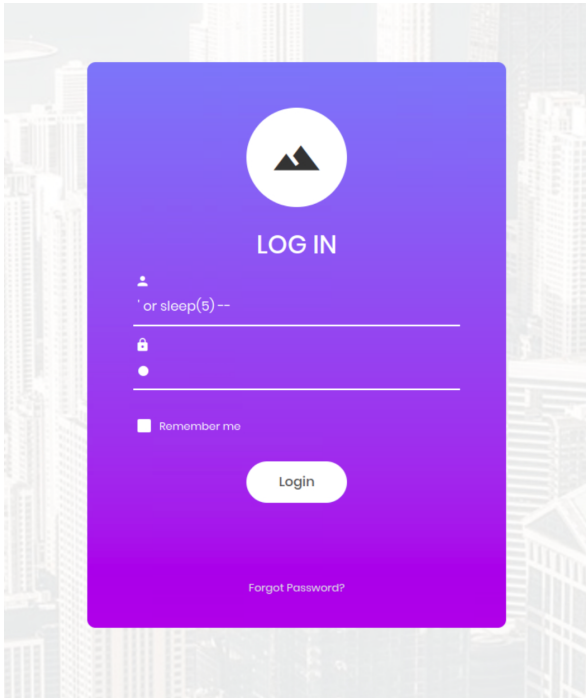

Figure 1.8.1.3.3.1: An attempt to get the application to 'sleep' for 5 seconds but unsuccessful as the wrong comment character is used

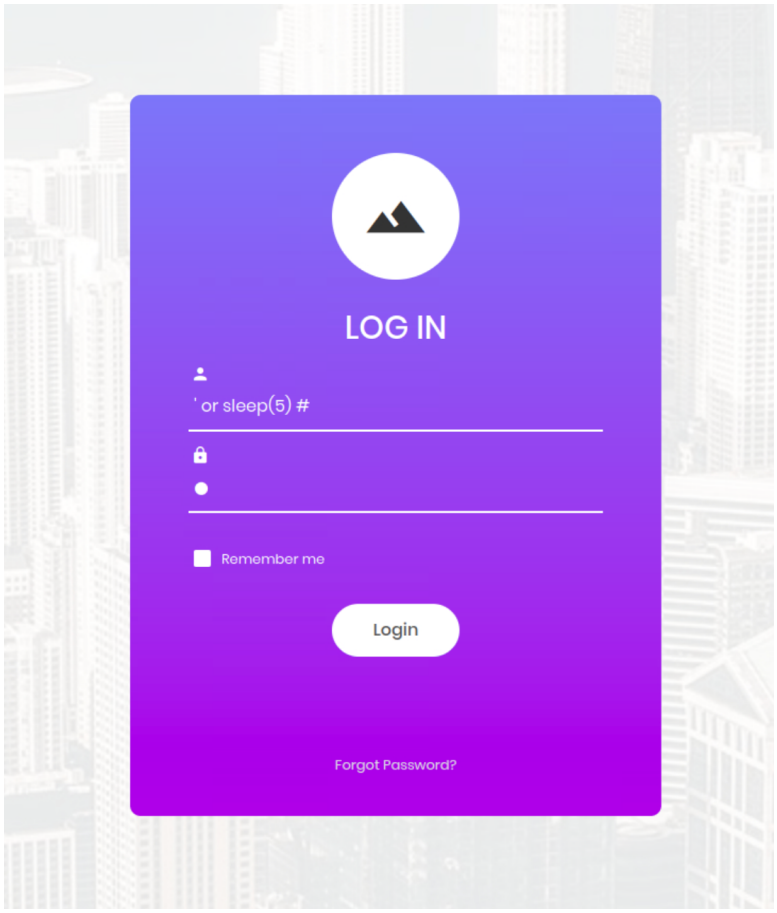

Figure 1.8.1.3.3.2: A successful attempt to get the application to 'sleep' for 5 seconds

1.8.1.3.4 Gaining Access

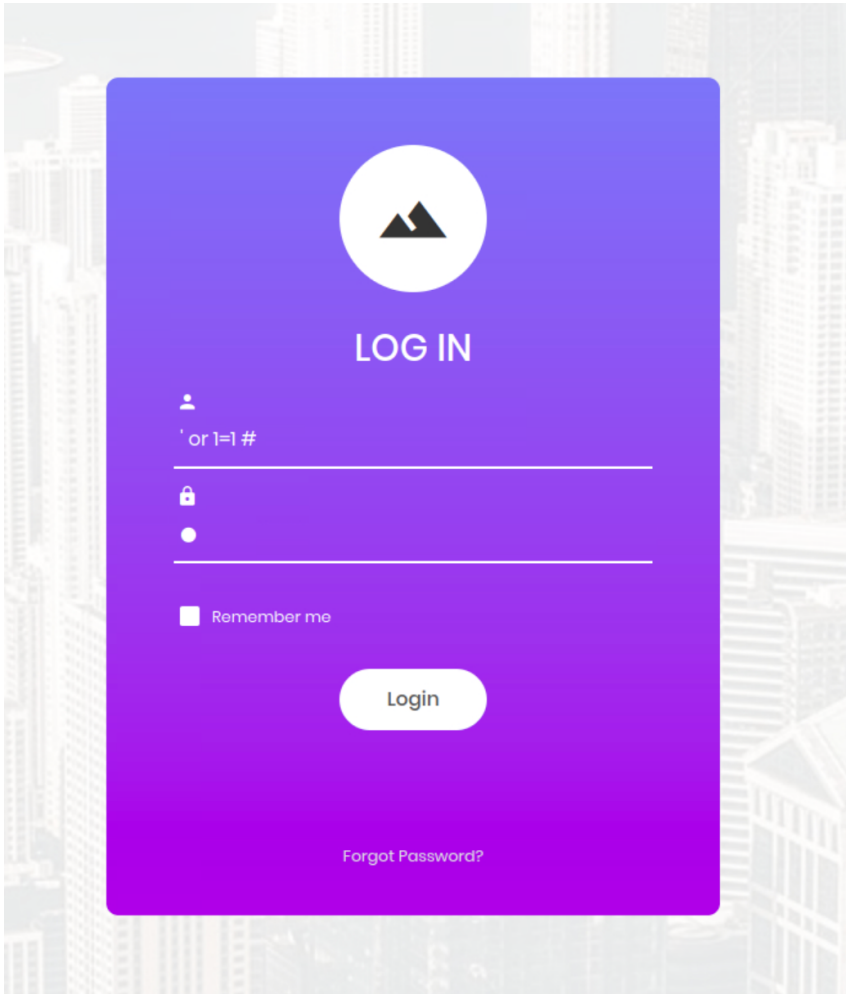

Figure 1.8.1.3.4.1: The statement used to gain access to the application

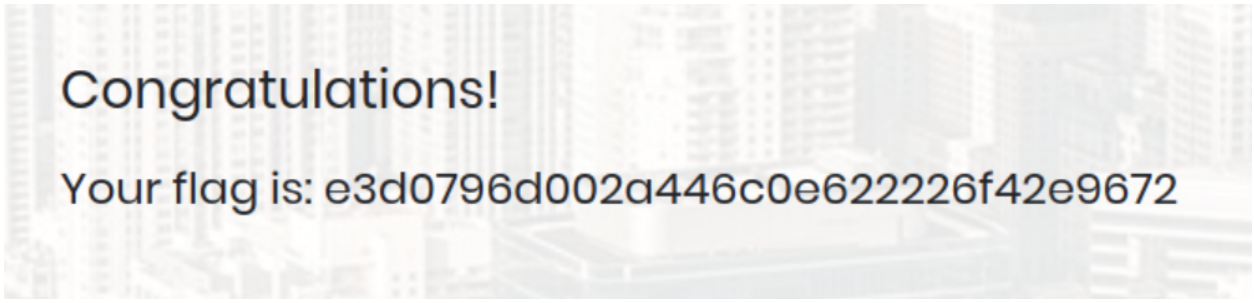

Figure 1.8.1.3.4.2: The flag, demonstrating the access to the application was granted

1.8.1.3.5 Gaining Administrator access

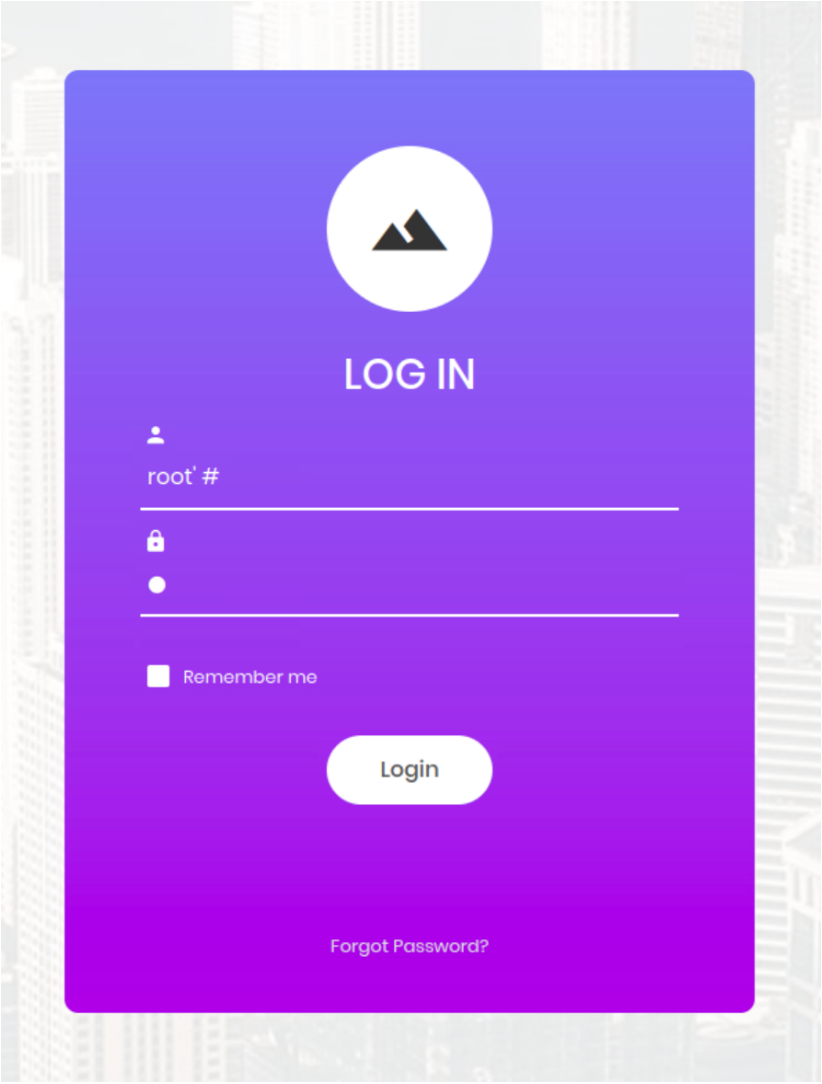

Figure 1.8.1.3.5.1: The failed attempt to gain administrator access using the 'root' username, implying the administrator username is not 'root'

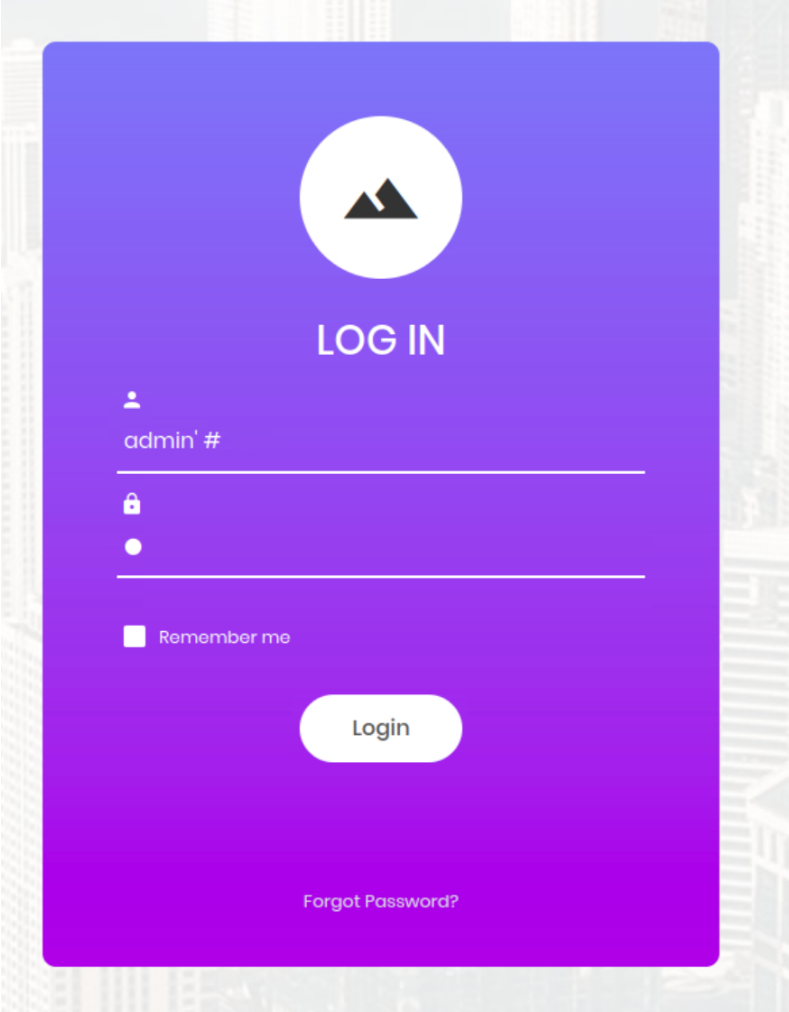

Figure 1.8.1.3.5.2: The successful attempt to gain administrator access using the 'admin' username, implying the administrator username is admin'

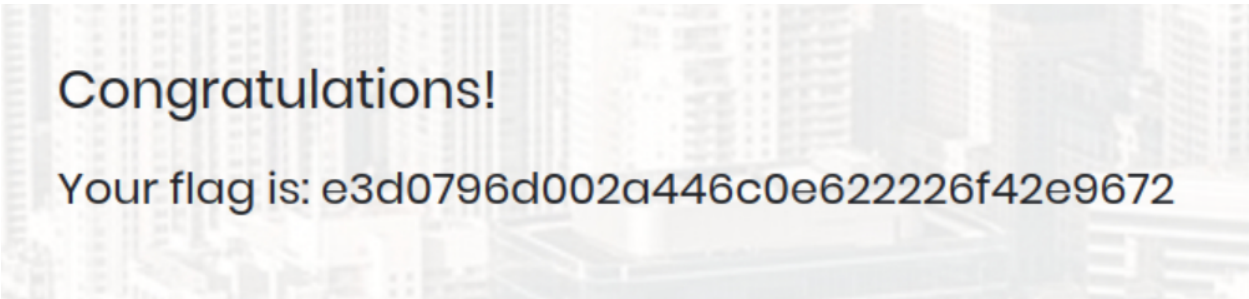

Figure 1.8.1.3.5.3: The flag, demonstrating the access to the application was granted

1.8.2 Code Rewrite

The code rewrite examples have all been written in PHP. This is due to the fact that the application is using an Apache server, on Debian, alongside MariaDB and therefore it is likely that a LAMP (Linux, Apache, MariaDB and PHP) architecture is being used.

It is assumed that before the code snippet there is already a connection to the database.

The result itself is stored within the variable '`$result`'.

1.8.2.1 Input Sanitisation

```
$username = $conn->real_escape_string($_GET["username"]);
$password = $conn->real_escape_string($_GET["password"]);

$select = "SELECT * FROM users WHERE username='" . $username . "' AND
password='" . $password . "';";

$result = $conn->query($select);
```

Figure 1.8.2.1.1: A code listing for using escaping functions to fix the current SQLi vulnerability

```
$username = $_GET["username"];
$password = $_GET["password"];

// an example blacklist, this is not exhaustive and is case insensitive
$blacklist = array("#", "--", "or 1=1", "drop", "sleep", "union",
"insert");

$regex = "/";
for ($i = 0; $i < sizeof($blacklist)-1; $i++) {
    $regex .= $blacklist[$i] . "|";
}

$regex .= $blacklist[sizeof($blacklist)-1] . "/i";

if (preg_match($regex, $username)) {
    echo "0 results";
    return 0;
}

$select = "SELECT * FROM users WHERE username='" . $username . "' AND
password='" . $password . "';";

$result = $conn->query($select);
```

Figure 1.8.2.1.2: A code listing for using a blacklist to fix the current SQLi vulnerability

```
$username = $conn->real_escape_string($_GET["username"]);
$password = $conn->real_escape_string($_GET["password"]);

// an example blacklist, this is not exhaustive and is case insensitive
$blacklist = array("#", "--", "or 1=1", "drop", "sleep", "union",
"insert");

$regex = "/";
for ($i = 0; $i < sizeof($blacklist)-1; $i++) {
    $regex .= $blacklist[$i] . "|";
}

$regex .= $blacklist[sizeof($blacklist)-1] . "/i";

if (preg_match($regex, $username)) {
    echo "0 results";
    return 0;
}

$select = "SELECT * FROM users WHERE username='" . $username . "' AND
password='" . $password . "';";

$result = $conn->query($select);
```

Figure 1.8.2.1.3: A code listing for using both escaping functions and a blacklist to fix the current SQLi vulnerability

1.8.2.2 Parameterised Input

```
$username = $_GET["username"];
$password = $_GET["password"];

$sql = $conn->prepare("SELECT * FROM users WHERE username=? AND
password=?;");

$query = $sql->bind_param('ss', $username, $password);
$sql->execute();

$result = $sql->get_result();
```

Figure 1.8.2.2.1: A code listing for using parameterised inputs to fix the current SQLi vulnerability

1.8.2.3 Stored Procedures

```
$username = $_GET["username"];
$password = $_GET["password"];

$conn->query("DROP PROCEDURE IF EXISTS getUser");

$procedure = "CREATE PROCEDURE getUser(IN username_in VARCHAR(100), IN
password_in VARCHAR(100)) SELECT * FROM users WHERE username=password_in
AND password=password_in";

$conn->query($procedure);

$sql = "CALL getUser('" . $username . "', '" . $password . "')";

$result = $conn->query($sql);
```

Figure 1.8.2.3.1: A code listing for using stored procedures to fix the current SQLi vulnerability

1.8.2.4 Combined Techniques

```
//escaping user input [1.8.2.1.1]
$username = $conn->real_escape_string($_GET["username"]);
$password = $conn->real_escape_string($_GET["password"]);

// blacklist [1.8.2.1.2]
$blacklist = array("#", "--", "or 1=1", "drop", "sleep", "union",
"insert");
$regex = "/";
for ($i = 0; $i < sizeof($blacklist)-1; $i++) {
    $regex .= $blacklist[$i] . "|";
}
$regex .= $blacklist[sizeof($blacklist)-1] . "/i";
if (preg_match($regex, $username)) {
    echo "0 results";
    return 0;
}

// stored procedure [1.8.2.3]
$conn->query("DROP PROCEDURE IF EXISTS getUser");
$procedure = "CREATE PROCEDURE getUser(IN username_in VARCHAR(100), IN
password_in VARCHAR(100)) SELECT * FROM users WHERE username=password_in
AND password=password_in";
$conn->query($procedure);

// parameterised input [1.8.2.2]
$sql = $conn->prepare("CALL getUser(?, ?)");

$query = $sql->bind_param('ss', $username, $password);
$sql->execute();
$result = $sql->get_result();
```

Figure 1.8.2.4.1: A code listing for the combined techniques to fix the current SQLi vulnerability

1.8.3 Glossary

- ***CIA*** - Confidentiality, Integrity and Availability
- ***LAMP*** - Linux, Apache, MariaDB and PHP
- ***MFA*** - Multi-Factor Authentication
- ***NIST*** - National Institute of Standards and Technology
- ***ORM*** - Object-Relational Mapping
- ***OWASP*** - Open Worldwide Application Security Project
- ***SDLC*** - Software Development Lifecycle
- ***SQLi*** - SQL Injection
- ***TDD*** - Test-Driven Development
- ***WAF*** - Web Application Firewall

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