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Experiment No.	07
GITHUB LINK :	https://github.com/TanayBPatel/CNSLab7

Executive Summary

This report documents the successful identification, exploitation, and mitigation of common web application vulnerabilities using the Damn Vulnerable Web Application (DVWA). Key vulnerabilities including SQL Injection, Cross-Site Scripting (Reflected and Stored), Command Injection, File Upload, CSRF, and others were successfully exploited under a low-security setting to understand their root causes and impact. Subsequently, the application's high-security configurations were enabled to demonstrate the effectiveness of modern mitigation techniques such as prepared statements, output encoding, and the use of anti-CSRF tokens. The experiment highlights the critical importance of secure coding practices, validating all user input, and implementing a defense-in-depth security posture for any web application.

Setup Notes

The experiment was conducted in a controlled virtual environment to ensure safety and prevent any impact on the host system or network.

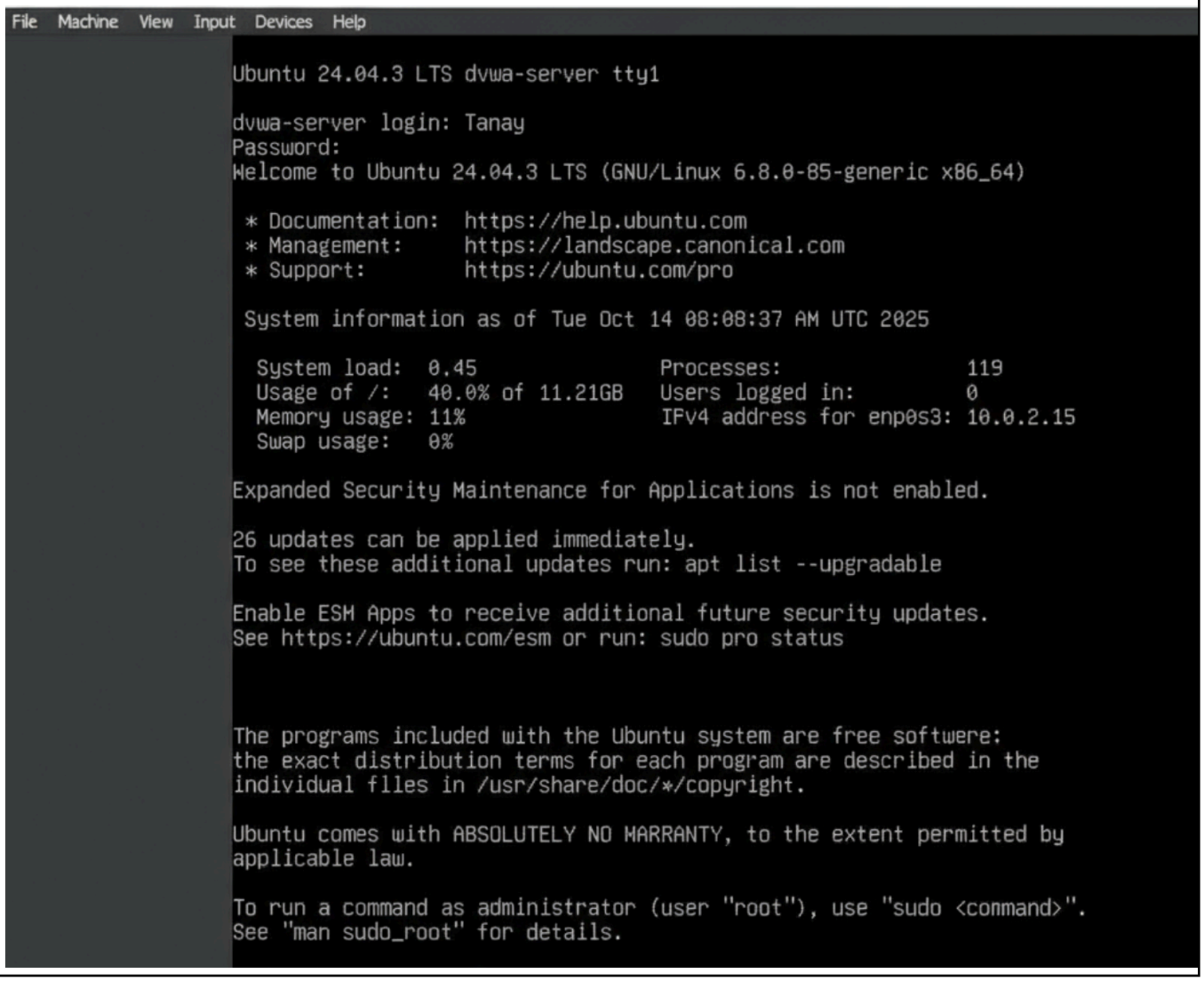
- **Virtualization Software:** Oracle VM VirtualBox
- **Operating System:** Ubuntu Server 22.04.5 LTS
- **Web Stack:** LAMP (Linux, Apache2, MariaDB, PHP)
- **Application:** DVWA (Damn Vulnerable Web Application) cloned from the official GitHub repository.
- **Network Configuration:** The VM was configured with a Bridged Network Adapter to be accessible from the host machine's browser. The IP address was masked for this report (e.g., 192.168.1.XXX).

Key Setup Commands:

1. **Use a VM** (VirtualBox / VMware / a cloud VM). DO NOT run this on your host machine or a public server — DVWA is intentionally vulnerable.
2. This guide assumes an **Ubuntu/Debian** VM with internet access and you have a user with sudo privileges.

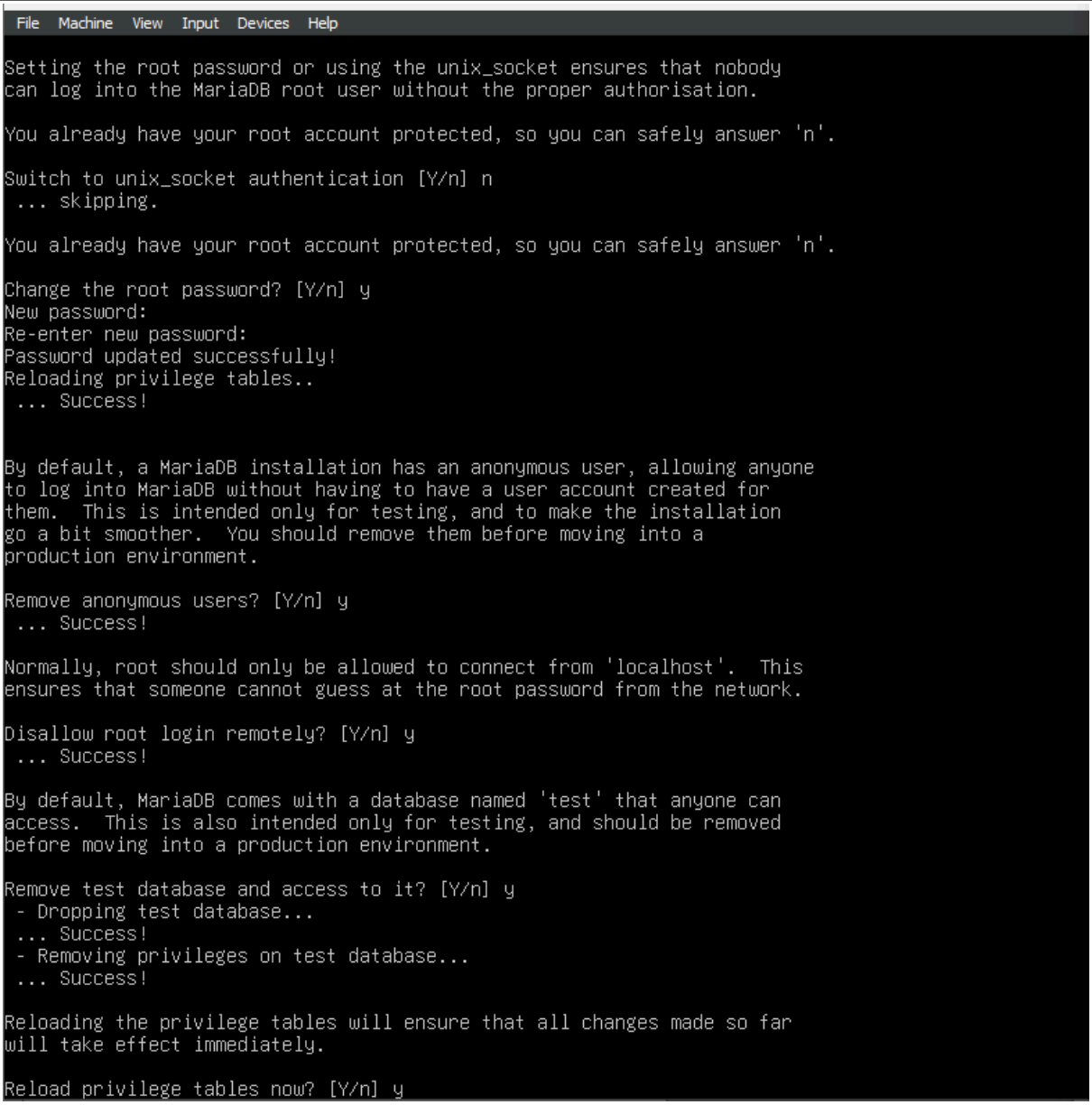
1. **Update system & install required packages (LAMP components + extras)**
   Commands:-
   sudo apt update
   sudo apt upgrade -y

   # Install Apache, MariaDB, PHP and required PHP extensions, git and unzip
   sudo apt install -y apache2 mariadb-server php php-mysqli php-xml php-gd php-mbstring git unzip curl



2. **Enable & start services**
   Commands:-
   sudo systemctl enable --now apache2
   sudo systemctl enable --now mariadb
   sudo systemctl status apache2 --no-pager
   sudo systemctl status mariadb --no-pager

3. **Secure MariaDB**
   Commands:-
   sudo mysql_secure_installation



4. **Download DVWA into web root**
   Commands:-
   cd /tmp
   git clone https://github.com/digininja/DVWA.git
   sudo mv DVWA /var/www/html/dvwa
   ls -la /var/www/html/dvwa

5. **Set ownership & permissions**
   Commands:-
   sudo chown -R www-data:www-data /var/www/html/dvwa
   sudo chmod -R 755 /var/www/html/dvwa

sudo cp /var/www/html/dvwa/config/config.inc.php.dist var/www/html/dvwa/config/config.inc.php

6. **Create DVWA database & user (MariaDB)**
   Commands:-
   Method A — using sudo mysql (works if root uses socket auth):
   sudo mysql -e "CREATE DATABASE IF NOT EXISTS dvwa;"
   sudo mysql -e "CREATE USER IF NOT EXISTS 'dvwauser'@'localhost' IDENTIFIED BY
   sudo mysql -e "GRANT ALL PRIVILEGES ON dvwa.* TO 'dvwauser'@'localhost';"
   sudo mysql -e "FLUSH PRIVILEGES;"
   Method B — using mysql -u root -p (if you set root password):
   mysql -u root -p
   # then at mysql> prompt:

   CREATE DATABASE dvwa;
   CREATE USER 'dvwauser'@'localhost' IDENTIFIED BY 'dvwapass';
   GRANT ALL PRIVILEGES ON dvwa.* TO 'dvwauser'@'localhost';
   FLUSH PRIVILEGES;
   EXIT;

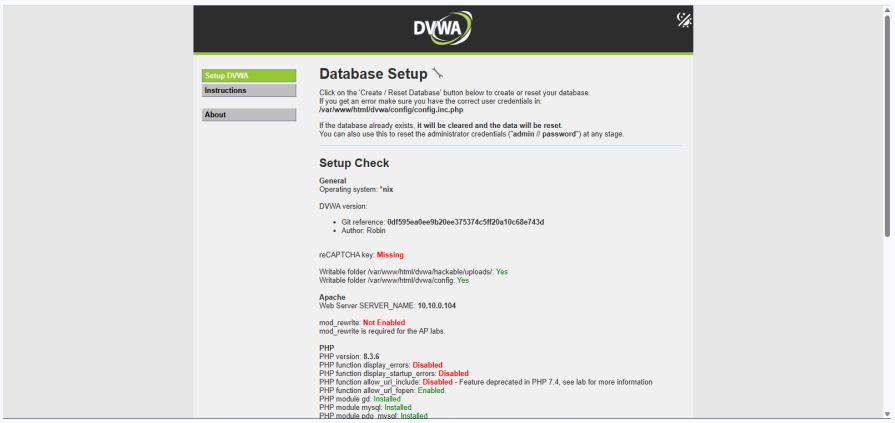
```
MariaDB [(none)]> CREATE DATABASE dvwa;
Query OK, 1 row affected (0.000 sec)

MariaDB [(none)]> CREATE USER 'dvwauser'@'localhost' IDENTIFIED BY 'dvwapass';
Query OK, 0 rows affected (0.003 sec)

MariaDB [(none)]> GRANT ALL PRIVILEDGES ON dvwa.* TO 'dvwauser'@'localhost';
ERROR 1064 (42000): You have an error in your SQL syntax; check the manual that corresponds to you
VILEDGES ON dvwa.* TO 'dvwauser'@'localhost'' at line 1
MariaDB [(none)]> GRANT ALL PRIVILEGES ON dvwa.* TO 'dvwauser'@'localhost';
Query OK, 0 rows affected (0.003 sec)

MariaDB [(none)]> FLUSH PRIVILEGES;
Query OK, 0 rows affected (0.000 sec)

MariaDB [(none)]> EXIT;
Bye
```

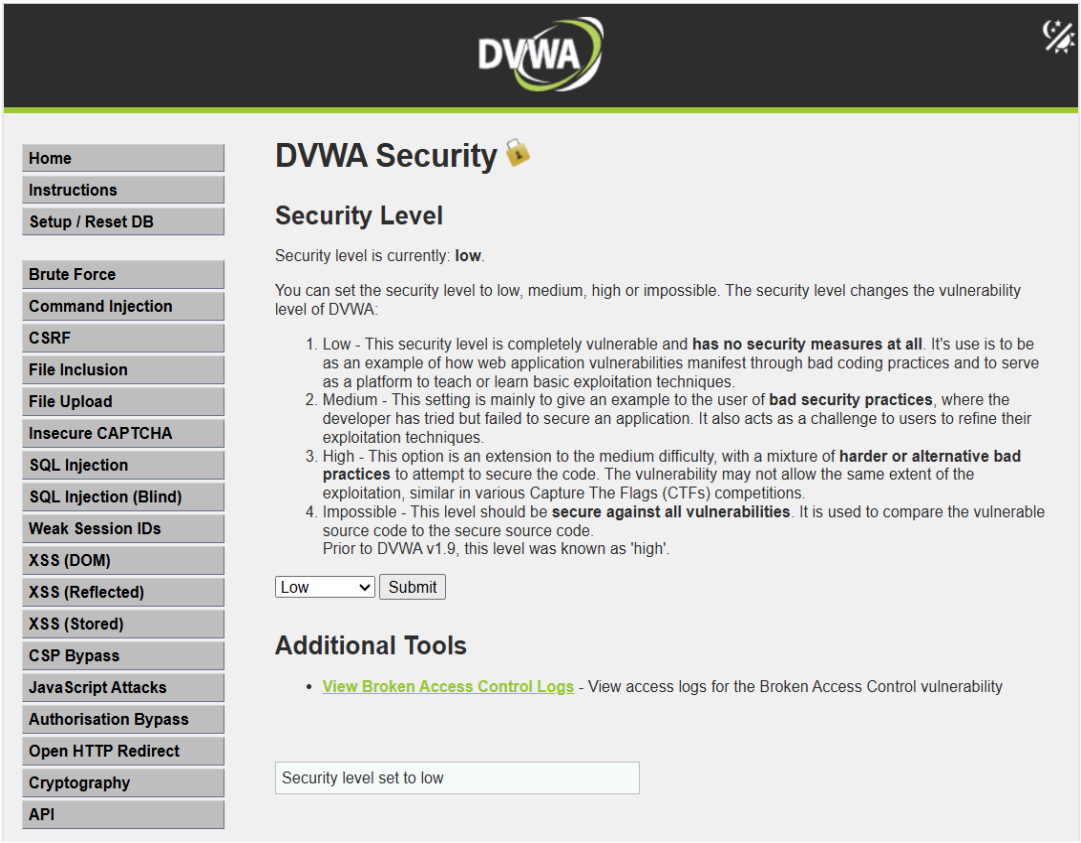
7. **Edit DVWA config to match DB credentials**
   Commands:-
   sudo nano /var/www/html/dvwa/config/config.inc.php

   # Find and set these values (exact lines may vary slightly):
   $_DVWA['db_server']   = 'localhost';
   $_DVWA['db_database'] = 'dvwa';
   $_DVWA['db_user']   = 'dvwauser';
   $_DVWA['db_password'] = 'dvwapass';

Part A: Setup & Baseline

This section confirms the successful deployment and initial configuration of DVWA.

Item	Evidence
DVWA Setup Page	
DVWA Login Page	

DVWA Security Level	

Security Level Explanation

The DVWA security setting changes how the application code handles user input to simulate different levels of protection:

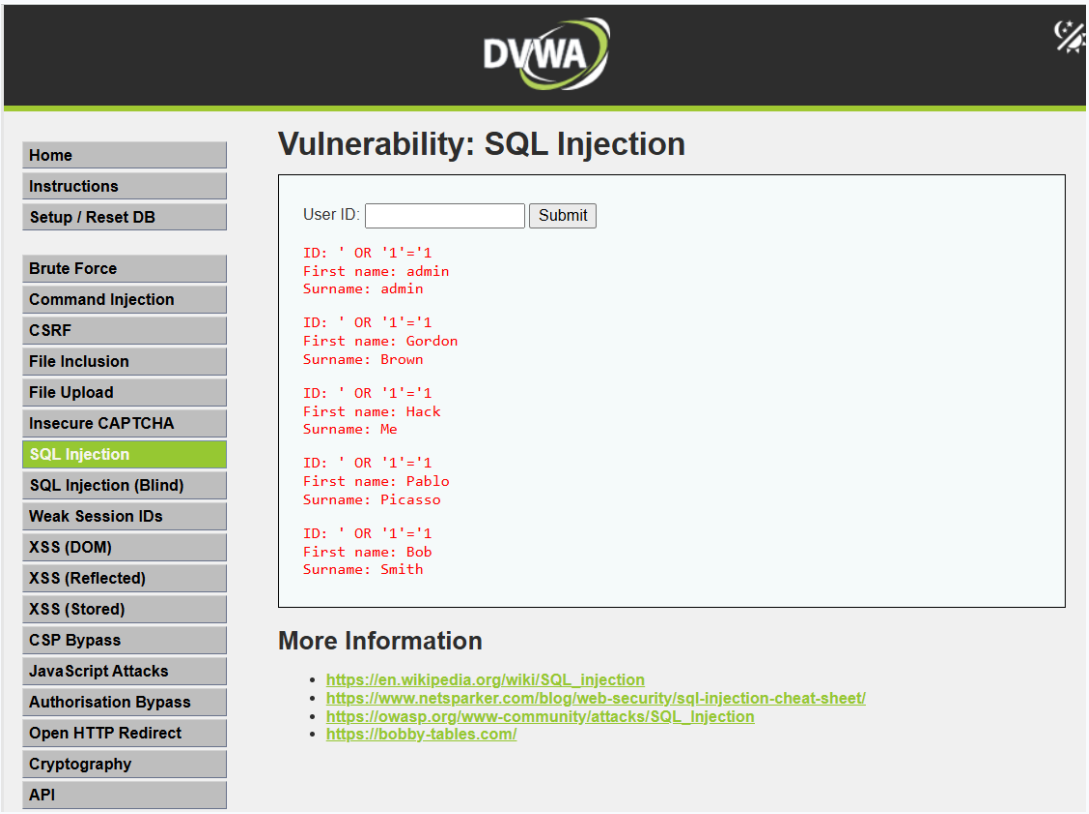
- **Low:** Implements no security measures, making it trivial to demonstrate basic exploits.
- **Medium:** Introduces basic, often flawed, security filters (e.g., blacklisting keywords) to teach bypass techniques.
- **High:** Implements stronger, modern defenses (e.g., prepared statements, CSRF tokens) that are much harder to exploit.

Part B & C: Basic Vulnerability Exploitation (Low Security)

The following vulnerabilities were identified and exploited with the security level set to **Low**.

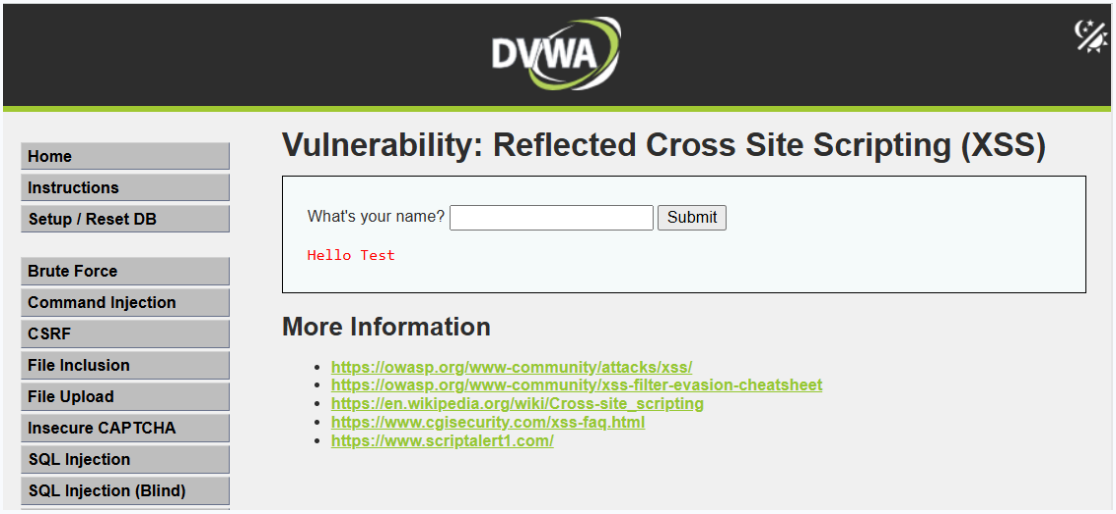
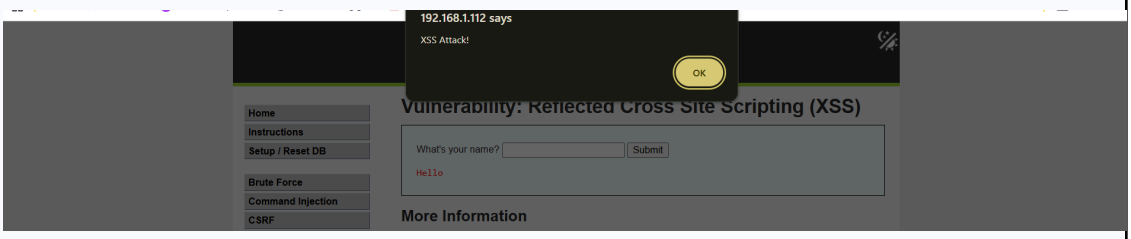
SQL Injection (SQLi)

Aspect	Details
Risk Rating	**High**

Exploitation Steps	1. Navigate to the "SQL Injection" page. 2. In the "User ID" input box, enter the payload: ' OR '1'='1 3. Click "Submit". The application will dump the user details for all users in the database.
Evidence	
Root Cause Analysis	The application directly concatenates the user's input into the SQL query without sanitization. This allows the input to be interpreted as part of the SQL command, altering the query's logic to bypass the WHERE clause and return all records.
Proposed Fix	Implement **Parameterized Queries (Prepared Statements)**. This practice separates the SQL code from the user-supplied data, ensuring the input is always treated as data and never as an executable command.

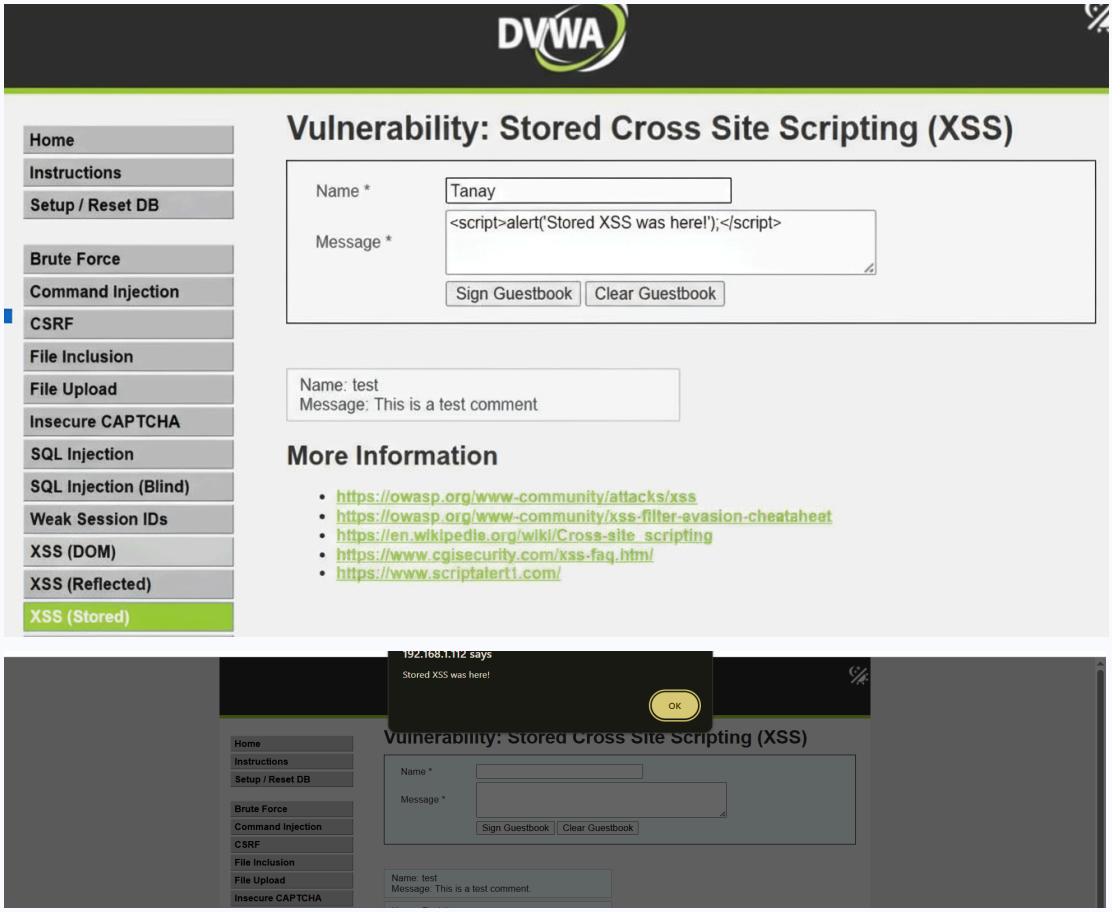
Reflected Cross-Site Scripting (XSS)

Aspect	**Details**
Risk Rating	**Medium**
Exploitation Steps	1. Navigate to the "XSS (Reflected)" page. 2. In the name input box, enter the payload: <script>alert('XSS Attack!');</script>

	3. Click "Submit". The browser executes the script, displaying a pop-up alert box.
Evidence	 
Root Cause Analysis	The application takes user input and reflects it directly back onto the webpage without proper output encoding. The browser misinterprets the malicious script as legitimate code and executes it.
Proposed Fix	Implement context-aware **Output Encoding**. Before rendering user input in HTML, convert special characters (e.g., < > " ') into their corresponding HTML entities (e.g., < > " ').

Stored Cross-Site Scripting (XSS)

Aspect	**Details**
Risk Rating	**High**
Exploitation Steps	1. Navigate to the "XSS (Stored)" page. 2. In the "Message" input box, enter the payload: <script>alert('Stored XSS was here!');</script> 3. Click "Sign Guestbook". The malicious script is saved to the database.

	4. The page reloads, and the script executes for the current user and for any future visitor to the page.
Evidence	
Root Cause Analysis	The application stores unsanitized user input in the database. When this stored data is retrieved and displayed to other users, it is rendered without output encoding, causing the malicious script to execute in their browsers.
Proposed Fix	A combination of **Input Validation** (to strip dangerous tags before storing) and strict **Output Encoding** (when displaying the data) is required for a robust defense.

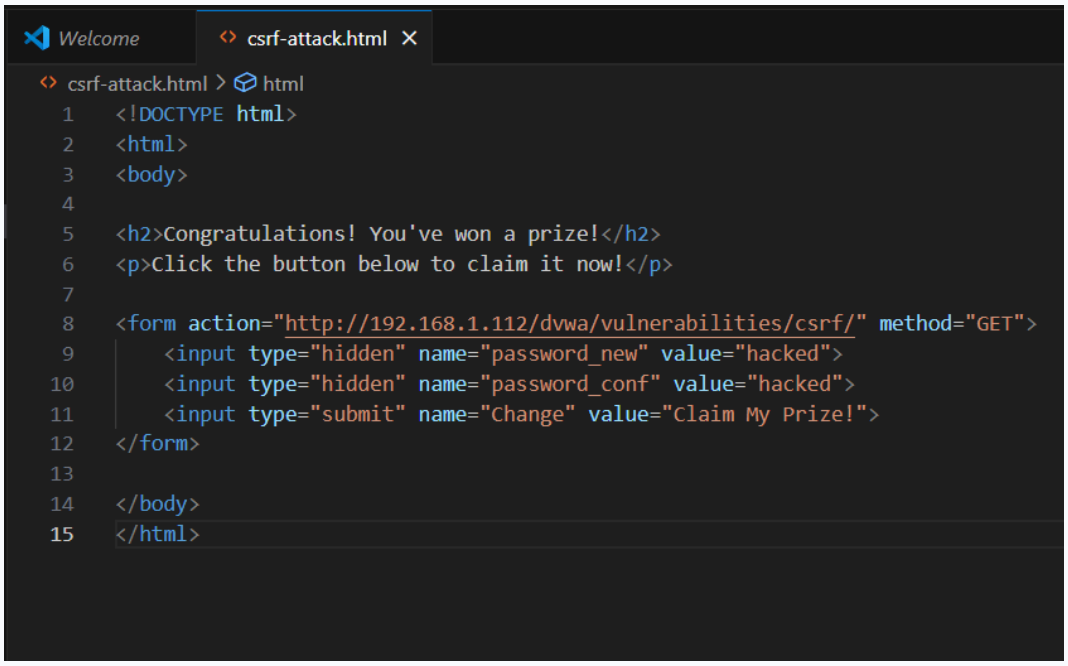
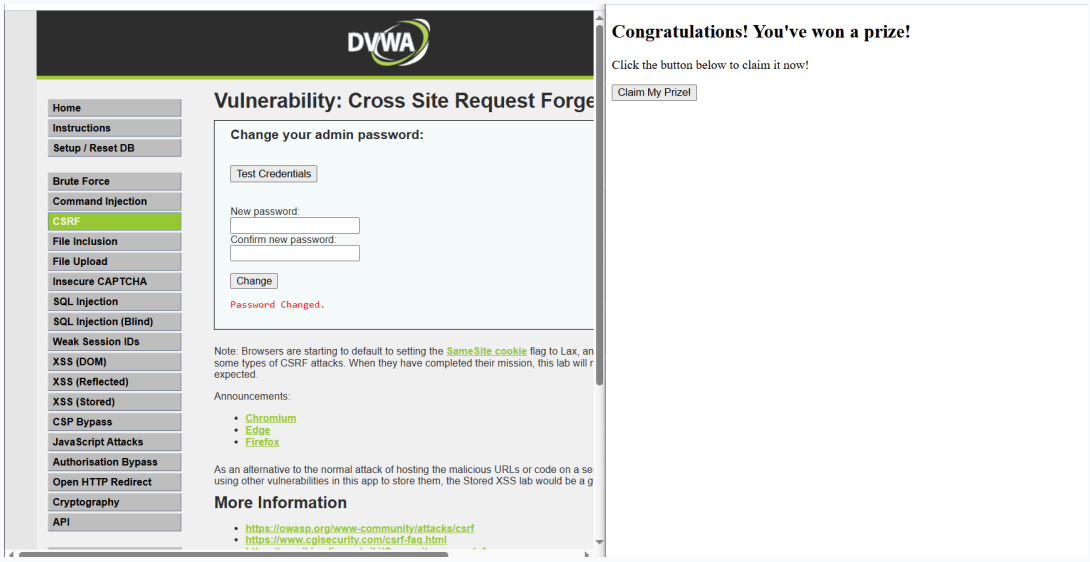
Brute Force

Aspect	**Details**
Risk Rating	**Medium**
Exploitation Steps	1. Log out of DVWA to access the login page. 2. Enter the username admin and a series of incorrect passwords (e.g., 123, password123,

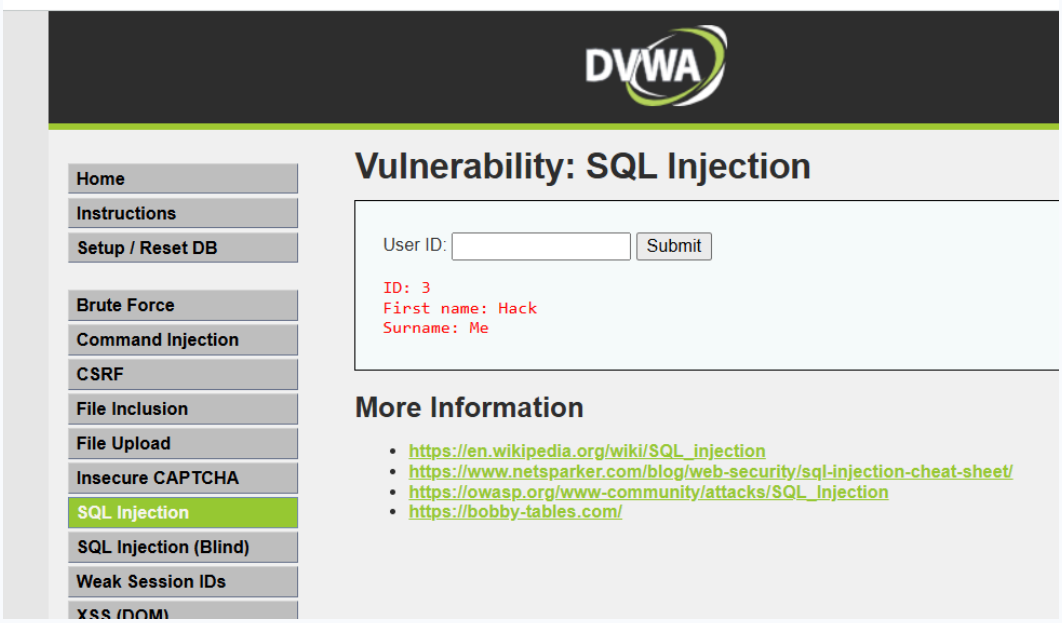
	test). 3. Observe that the application allows unlimited, rapid login attempts without any penalty, delay, or lockout. This behavior is vulnerable to automated attacks.
Evidence	
Root Cause Analysis	The login mechanism lacks essential security controls like rate-limiting or account lockout. It does not track failed login attempts, allowing an attacker to make an infinite number of password guesses.
Proposed Fix	Implement **Account Lockout** policies (e.g., lock account for 15 minutes after 5 failed attempts), introduce **Progressive Delays** between failed attempts, and use a **CAPTCHA** to deter automated bots.

Cross-Site Request Forgery (CSRF)

Aspect	**Details**
Risk Rating	**Medium**
Exploitation Steps	1. Create a malicious HTML page (csrf-attack.html) containing a hidden form that targets the DVWA password change function. 2. With a valid session in DVWA, open the malicious page in another browser tab. 3. The victim clicks the "Claim My Prize!" button, which unknowingly submits the password change request to DVWA. 4. The password for the admin account is successfully changed to "hacked".

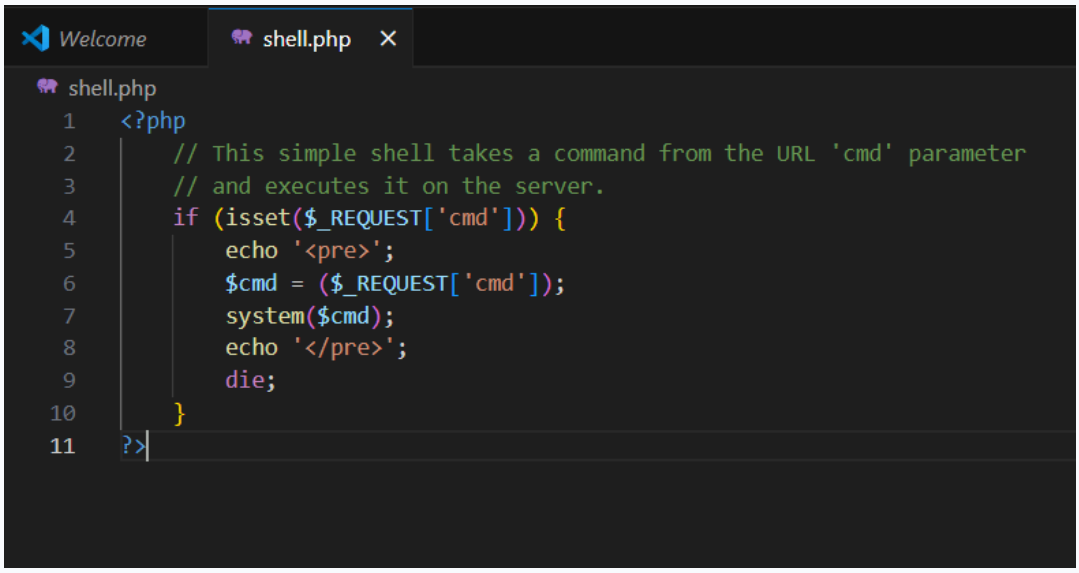
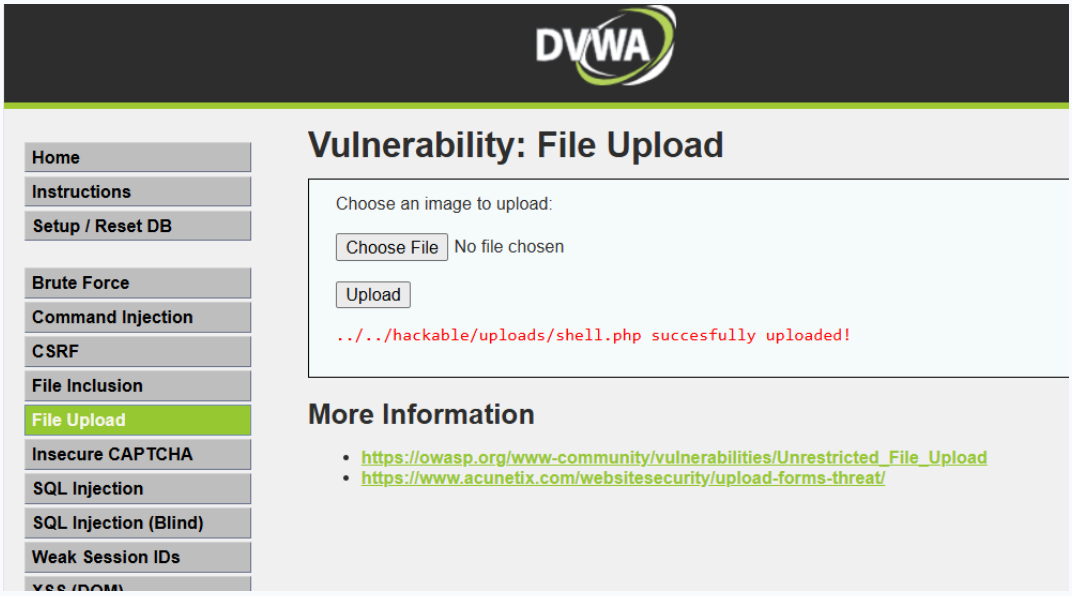
Evidence	 
Root Cause Analysis	The application fails to verify the origin and intent of the request. It processes the state-changing action (password change) based solely on the user's active session cookie, without requiring a unique, secret token to confirm the request came from the legitimate application form.
Proposed Fix	Implement **Anti-CSRF Tokens**. A unique, unpredictable token should be embedded in every state-changing form. The server must validate this token upon submission to ensure the request is legitimate.

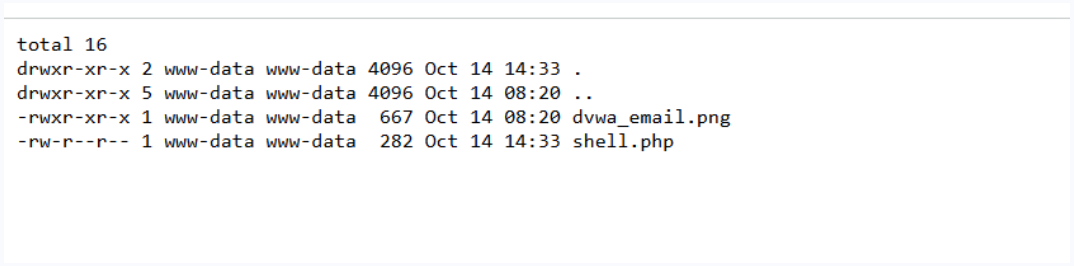
Insecure Direct Object References (IDOR)

Aspect	Details
Risk Rating	**Medium**
Exploitation Steps	1. Navigate to the "SQL Injection" page and submit User ID 1. 2. Observe the URL, which contains ?id=1. 3. Manually modify the URL in the browser's address bar, changing the id parameter to 2, then 3, etc. 4. The application displays the information for other users, proving a lack of authorization checks.
Evidence	
Root Cause Analysis	The application retrieves data based solely on the user-supplied object identifier (the id parameter). It fails to perform an authorization check to verify that the currently logged-in user has the permission to view the requested object.
Proposed Fix	Implement strict, server-side **Access Control Checks**. For every request, the application must verify that the authenticated user's session is authorized to access the specific resource ID being requested.

Part D: File and Functionality Exploitation (Low Security)

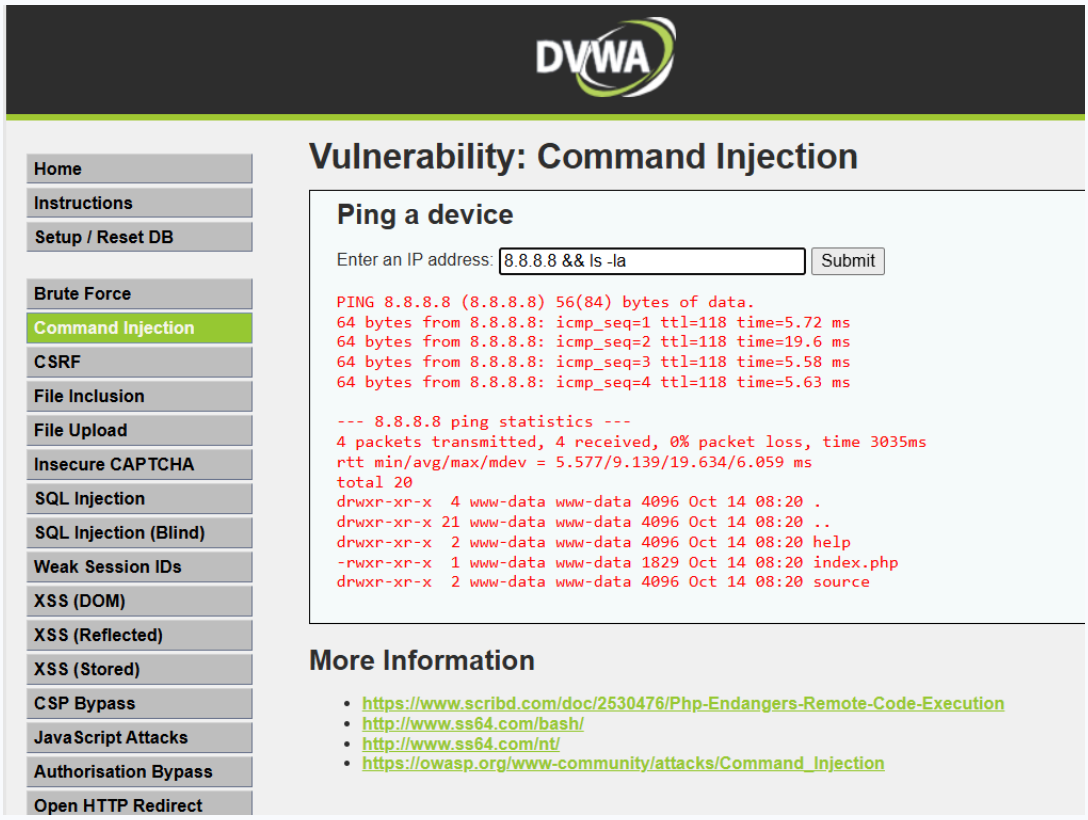
File Upload Vulnerability

Aspect	Details
Risk Rating	**High**
Exploitation Steps	1. Create a simple PHP web shell and save it as shell.php. 2. Navigate to the "File Upload" page. 3. Upload the shell.php file. The application accepts it without validation. 4. Access the uploaded shell via its URL (.../hackable/uploads/shell.php). 5. Execute OS commands by passing them in a cmd URL parameter (e.g., ?cmd=whoami).
Evidence	 

	
Root Cause Analysis	The application has no server-side validation to check the file's extension, content type, or contents. It allows executable files (.php) to be uploaded to a web-accessible directory, leading to Remote Code Execution.
Proposed Fix	Implement a multi-layered defense: **whitelist** safe file extensions, validate the file's **MIME type** on the server, **rename** uploaded files to a random string, and store them **outside the web root directory**.

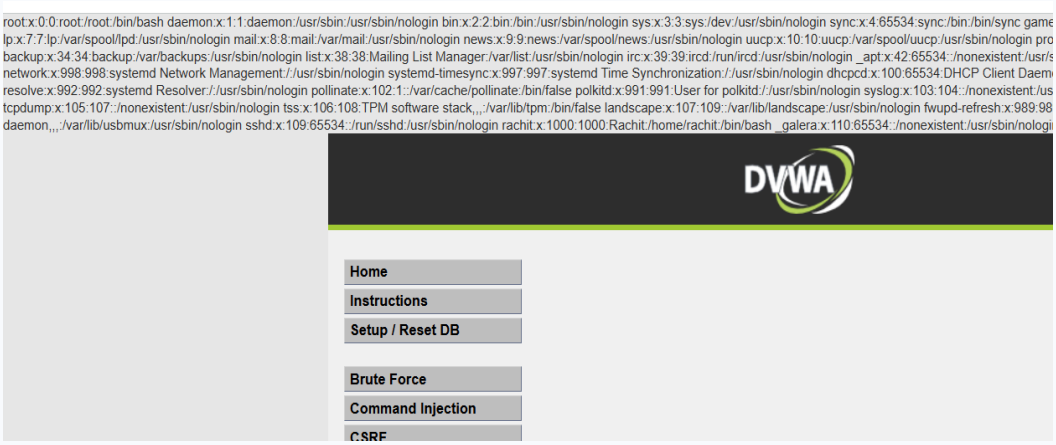
Command Injection

Aspect	**Details**
Risk Rating	**High**
Exploitation Steps	1. Navigate to the "Command Injection" page. 2. In the IP address input box, enter the payload: 8.8.8.8 && ls –la 3. Click "Submit". The application executes both the ping command and the injected ls -la command, displaying the output of both on the page.

Evidence	
Root Cause Analysis	The application takes user input and passes it directly to a system shell command without sanitizing shell metacharacters like &, `
Proposed Fix	The best practice is to **avoid calling system commands** with user input. If unavoidable, input must be **strictly sanitized** using a whitelist of allowed characters, and parameters should be passed safely to system calls.

File Inclusion

Aspect	**Details**
Risk Rating	**High**
Exploitation Steps	1. Navigate to the "File Inclusion" page. 2. Observe the page parameter in the URL (?page=include.php). 3. Manipulate the page parameter with a directory traversal payload to read a sensitive system file: ../../../../../../etc/passwd 4. The application includes and displays the contents of the /etc/passwd file.

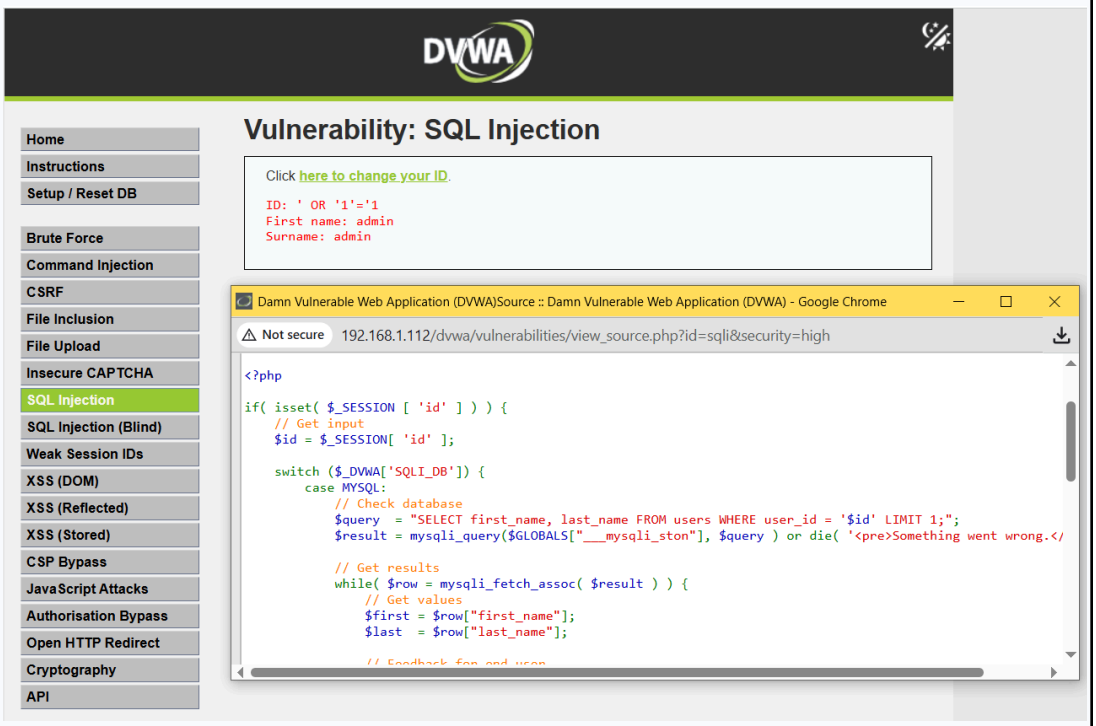
Evidence	
Root Cause Analysis	The application uses user-supplied input directly in a file inclusion function without proper validation. It fails to sanitize or restrict the input, allowing an attacker to use directory traversal sequences (../) to access arbitrary files on the server.
Proposed Fix	**Use a whitelist approach**. Never accept full filenames or paths from the user. Instead, map clean, user-friendly input (e.g., ?page=about) to a hardcoded, safe file path on the server.

Part E: Defense & Remediation

The following tests were conducted with the DVWA security level set to **High** to demonstrate the effectiveness of implemented security controls.

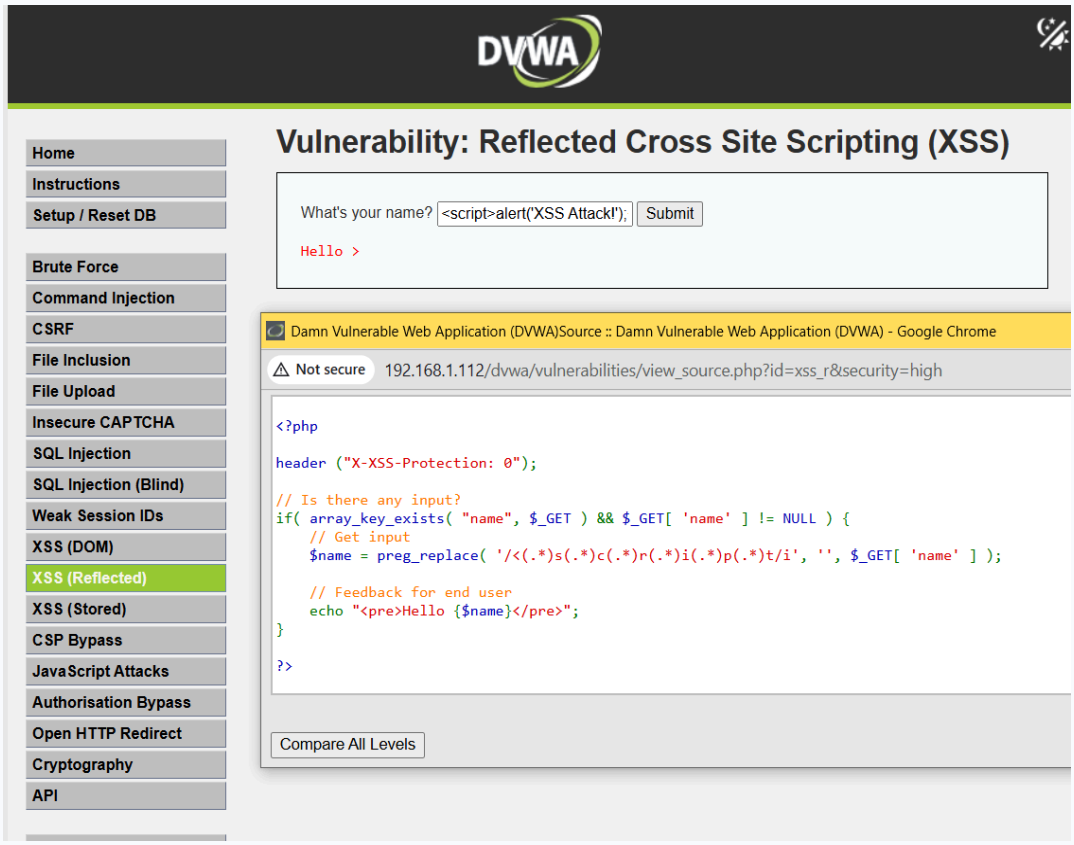
SQL Injection Mitigation

Aspect	Details
Attack Attempt	The "SQL Injection" page was visited. On High security, the input field is removed entirely.
Result	**Failed.** The attack vector is eliminated as the page no longer accepts user input for the query. It securely retrieves data based on the logged-in user's session.

Evidence	

Reflected XSS Mitigation

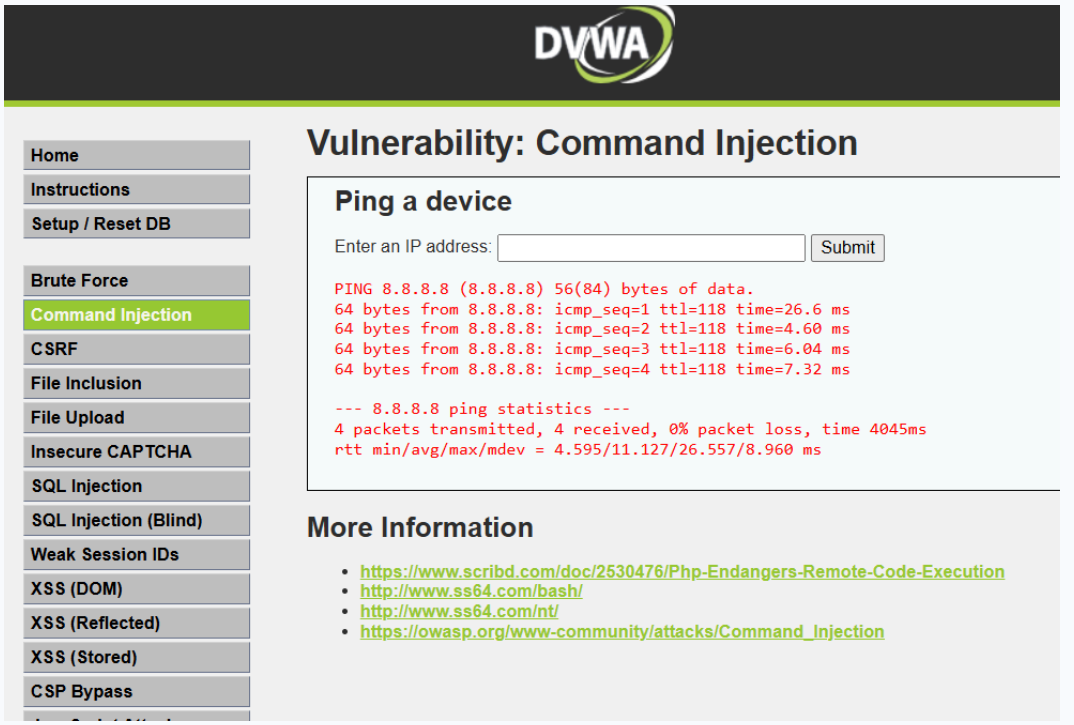
Aspect	Details
Attack Attempt	The payload <script>alert('XSS Attack!');</script> was submitted on the "XSS (Reflected)" page.
Result	**Failed.** The script was not executed. Instead, it was rendered as harmless text on the page due to proper output encoding.

Evidence	

Command Injection Mitigation

Aspect	Details
Attack Attempt	The payload 8.8.8.8 && ls -la was submitted on the "Command Injection" page.
Result	**Failed.** The application rejected the input as invalid because it contained non-IP address characters. The malicious command was not executed.

Evidence


DVWA
Home
Instructions
Setup / Reset DB
Brute Force
Command Injection
CSRF
File Inclusion
File Upload
Insecure CAPTCHA
SQL Injection
SQL Injection (Blind)
Weak Session IDs
XSS (DOM)
XSS (Reflected)
XSS (Stored)
CSP Bypass
Vulnerability: Command Injection
Ping a device
Enter an IP address:
Submit
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_seq=1 ttl=118 time=26.6 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=118 time=4.60 ms
64 bytes from 8.8.8.8: icmp_seq=3 ttl=118 time=6.04 ms
64 bytes from 8.8.8.8: icmp_seq=4 ttl=118 time=7.32 ms
--- 8.8.8.8 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 4045ms
rtt min/avg/max/mdev = 4.595/11.127/26.557/8.960 ms
More Information
https://www.scribd.com/doc/2530476/Php-Endangers-Remote-Code-Execution
http://www.ss64.com/bash/
http://www.ss64.com/nt/
https://owasp.org/www-community/attacks/Command_Injection


DVWA
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SQL Injection
SQL Injection (Blind)
Weak Session IDs
XSS (DOM)
Vulnerability: Command Injection
Ping a device
Enter an IP address:
8.8.8.8 && ls -la
Submit
More Information
https://www.scribd.com/doc/2530476/Php-Endangers-Remote-Code-Execution
http://www.ss64.com/bash/
http://www.ss64.com/nt/
https://owasp.org/www-community/attacks/Command_Injection

Section 2: Implementation of Custom Fixes

To further demonstrate an understanding of remediation, custom PHP scripts were created and deployed to the server to fix three key vulnerabilities from scratch.

SQL Injection Mitigation (Prepared Statements)

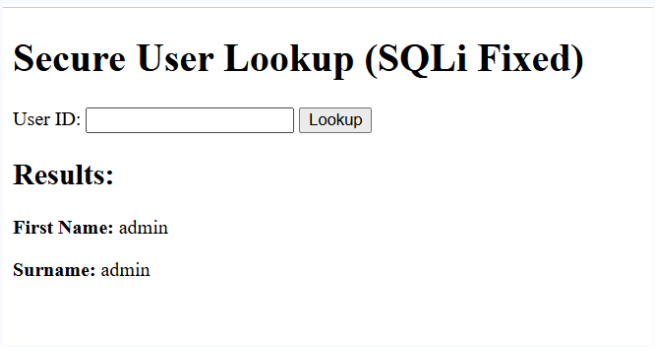
Remediation Script

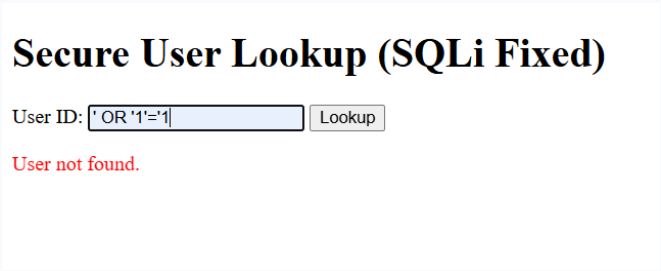
```php
<?php
// fix_sqli.php - Secure user lookup with Prepared Statements

// Database credentials from DVWA's config
$db_server = '127.0.0.1';
$db_user = 'dvwauser';
$db_password = 'dvwapass';
$db_database = 'dvwa';

// Establish a connection
$conn = new mysqli($db_server, $db_user, $db_password,
$db_database);
if ($conn->connect_error) {
    die("Connection failed: " . $conn->connect_error);
}
$user_id = '';
$first_name = '';
$surname = '';
$error_message = '';
if (isset($_GET['id']) && $_GET['id'] != '') {
    $user_id = $_GET['id'];

    // 1. Prepare the statement with a placeholder (?)
    $stmt = $conn->prepare("SELECT first_name, last_name FROM
users WHERE user_id = ?");
    // 2. Bind the user input to the placeholder
    // 's' means the input is treated as a string
    $stmt->bind_param("s", $user_id);
    // 3. Execute the safe query
    $stmt->execute();
    $result = $stmt->get_result();
    if ($result->num_rows > 0) {
        $row = $result->fetch_assoc();
        $first_name = $row['first_name'];
        $surname = $row['last_name'];
    } else {
        $error_message = "User not found.";
    }
    $stmt->close();
}
$conn->close();
?>
```

	 `` <!DOCTYPE html> <html> <head> <title>Secure User Lookup</title> </head> <body> Secure User Lookup (SQLi Fixed) <form method="GET" action=""> <label for="id">User ID:</label> <input type="text" id="id" name="id"> <input type="submit" value="Lookup"> </form> <?php if ($first_name): ?> Results: First Name: <?php echo htmlspecialchars($first_name); ?> Surname: <?php echo htmlspecialchars($surname); ?> <?php endif; ?> <?php if ($error_message): ?> <?php echo htmlspecialchars($error_message); ?> <?php endif; ?> </body> </html> ```
Explanation of Fix	The code uses a **prepared statement** (`$conn->prepare(...)`). The user input is never mixed with the SQL query itself. Instead, it is sent to the database separately using `bind_param()`, ensuring it is always treated as data, not as a command, thus neutralizing the SQL injection attack.
Evidence	

	 This proves the fix worked because the malicious payload was treated as a literal string, not a command, and no user has the ID `' OR '1'='1`

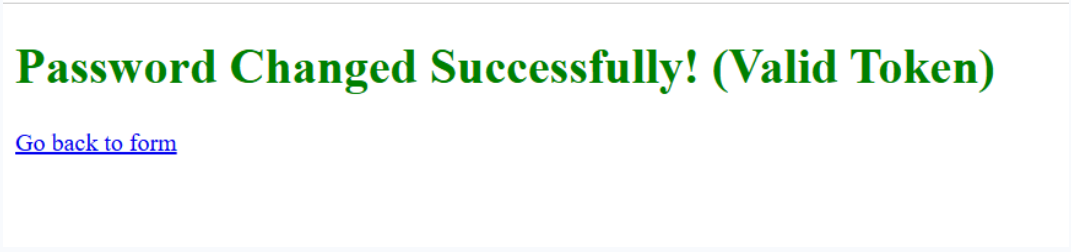
Reflected XSS Mitigation (Output Encoding)

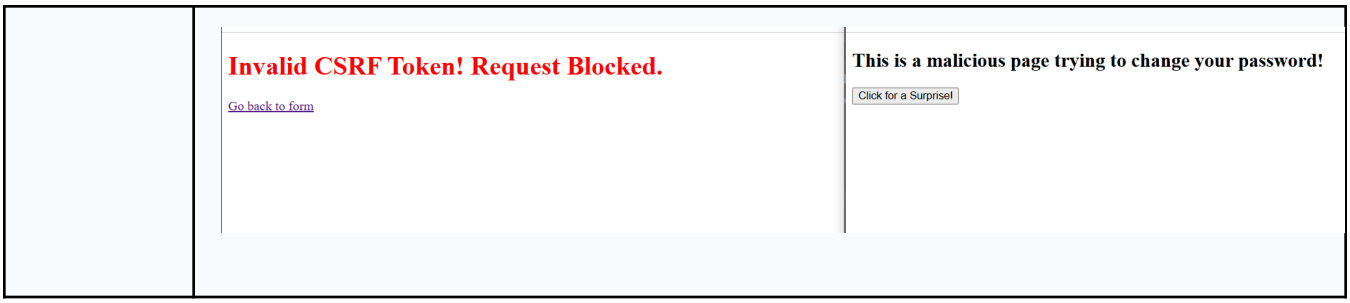
Remediation Script	`<?php` `// fix_xss.php - Secure output encoding to prevent Reflected XSS` `$name = '';` `if (isset($_GET['name'])) {` `$name = $_GET['name'];` `}` `?>` `<!DOCTYPE html>` `<html>` `<head>` `<title>Secure Hello Page</title>` `</head>` `<body>` `<h1>Secure Hello Page (XSS Fixed)</h1>` `<form method="GET" action="">` `<label for="name">What's your name?</label>` `<input type="text" id="name" name="name">` `<input type="submit" value="Submit">` `</form>` `<?php if ($name !== ''): ?>` `<h2>` `<?php` `// Use htmlspecialchars() to encode output.` `// This converts < into < and > into >` `echo "Hello " . htmlspecialchars($name, ENT_QUOTES, 'UTF-8');` `?>` `</h2>` `<?php endif; ?>` `</body>` `</html>`
Explanation of Fix	The vulnerability is mitigated by processing all user-supplied output through the `htmlspecialchars()` function. This function converts characters that have special meaning in HTML (like < and >) into their safe entity

	equivalents (`<` and `>`). This ensures the browser displays the input as plain text rather than executing it as a script.
Evidence	  The alert box **will not** appear. This proves the fix worked because the browser treated the encoded script as harmless text.

CSRF Mitigation (Anti-CSRF Tokens)

Remediation Script	```<?php // fix_csrf_form.php - A form protected with an Anti-CSRF token session_start(); if (empty($_SESSION['csrf_token'])) { $_SESSION['csrf_token'] = bin2hex(random_bytes(32)); }$token = $_SESSION['csrf_token']; ?> <!DOCTYPE html> <html><head> <title>Secure Password Change</title></head> <body> Change Your Password (CSRF Protected) ```

	<form method="POST" action="fix_csrf_process.php"> <label for="password">New Password:</label> <input type="password" id="password" name="password_new"> <input type="hidden" name="csrf_token" value="<?php echo htmlspecialchars($token); ?>"> <input type="submit" value="Change Password"> </form></body></html><?php // fix_csrf_process.php - Validates the Anti-CSRF token session_start(); $message = ''; $color = 'red'; // Check if the submitted token matches the one in the session if (isset($_POST['csrf_token'], $_SESSION['csrf_token']) && hash_equals($_SESSION['csrf_token'], $_POST['csrf_token'])) { $message = "Password Changed Successfully! (Valid Token)"; $color = 'green'; } else { $message = "Invalid CSRF Token! Request Blocked."; $color = 'red'; } unset($_SESSION['csrf_token']); ?> <!DOCTYPE html> <html><head><title>Processing Request</title></head><body> <h1 style="color: <?php echo $color; ?>;"><?php echo htmlspecialchars($message); ?></h1> Go back to form </body> </html>
Explanation of Fix	This fix prevents CSRF by implementing the **Synchronizer Token Pattern**. The server requires a secret, unique, and unpredictable token with every state-changing request. An attacker's malicious page cannot guess or access this token, so any forged request submitted from it will be invalid. The `hash_equals()` function provides a secure way to compare the tokens, protecting against timing attacks.
Evidence	



Lessons Learned & Recommended Hardening Checklist

Lessons Learned

The primary lesson from this experiment is that all user-supplied input must be treated as untrusted and potentially malicious. A defense-in-depth strategy is essential, as relying on a single security control is often insufficient. Secure coding is not about a single technique but a mindset of anticipating adversarial actions at every step. Key principles demonstrated include the importance of server-side validation, separating data from commands, implementing strong authorization checks, and ensuring the integrity of user requests.

Recommended LAMP Hardening Checklist

- **Input Validation:**
  - [ ] Use whitelisting over blacklisting for all user input.
  - [ ] Enforce strict data types, character sets, and length limits.
- **Database Security:**
  - [ ] Use Parameterized Queries (Prepared Statements) for all database access to prevent

SQLi.
    - [ ] Apply the Principle of Least Privilege: ensure the web application's database user has only the minimum required permissions.
- **Output Handling:**
    - [ ] Implement context-aware output encoding for all user-supplied data displayed in HTML, JS, and CSS to prevent XSS.
- **Authentication & Session Management:**
    - [ ] Enforce strong password policies.
    - [ ] Implement account lockout and rate-limiting on login forms to prevent brute-forcing.
    - [ ] Use anti-CSRF tokens for all state-changing actions.
- **Access Control:**
    - [ ] Perform server-side authorization checks for every request to prevent IDOR.
- **File Handling:**
    - [ ] Whitelist allowed file extensions and MIME types for uploads.
    - [ ] Rename all uploaded files to a random string.
    - [ ] Store uploaded files outside of the web root directory.
- **System Interaction:**
    - [ ] Avoid passing user input to system shell commands. Use language-native functions where possible.
    - [ ] If shell commands are necessary, strictly sanitize all input.

Conclusion :

During this experiment, I worked on identifying and fixing typical web application flaws using DVWA, including session fixation, SQL injection, insecure direct object references, and reflected XSS. The activity showed how weak validation or session handling can lead to attacks. Implementing input checks, parameterized queries, secure sessions, and output encoding proved effective in improving the overall security of web applications.