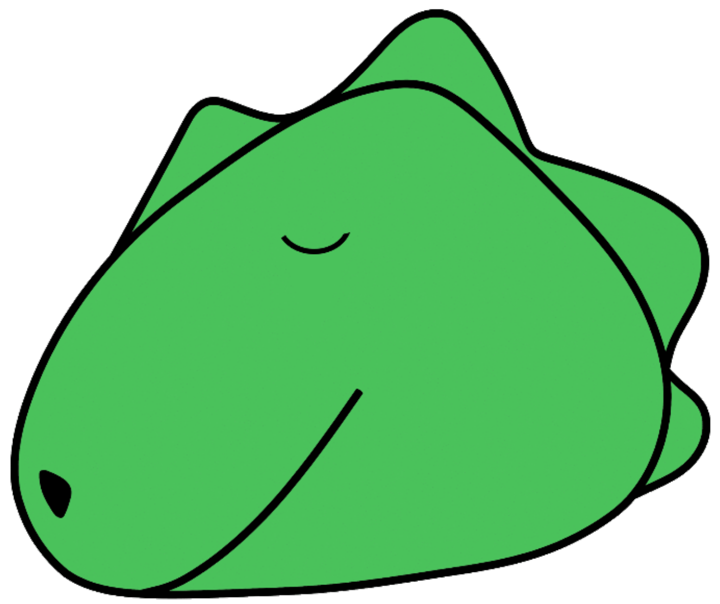
OWASP TimeGap Theory Handbook



Abhi M Balakrishnan

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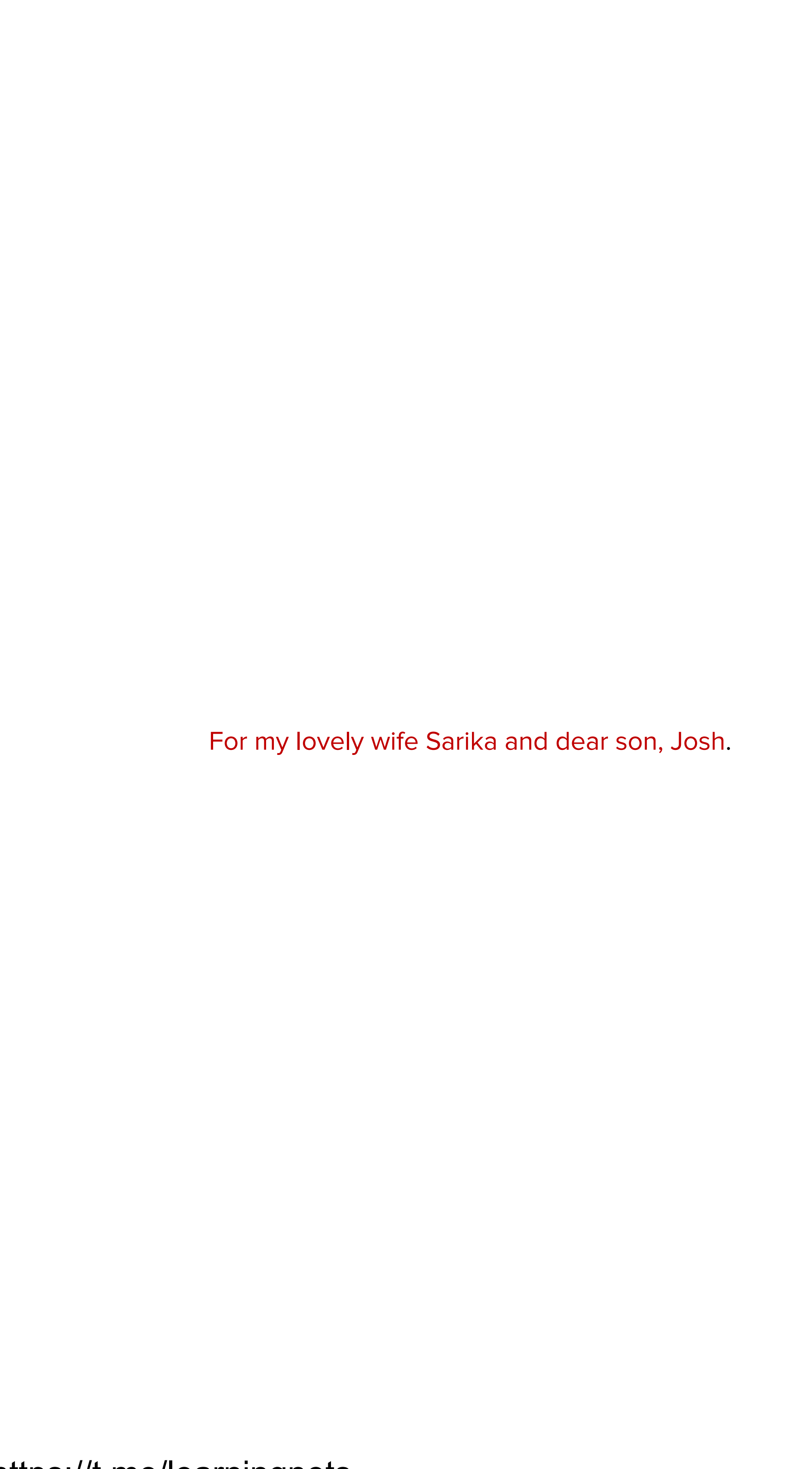

For my lovely wife Sarika and dear son, Josh.

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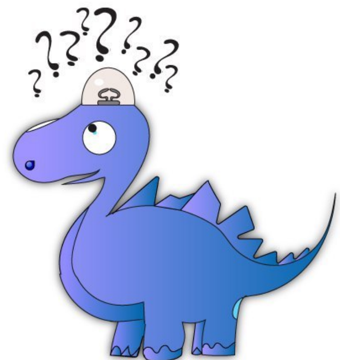
CHAPTER 0

Welcome!

This handbook is all about TOC/TOU vulnerabilities.
Welcome aboard and let's get started!



People often ask, "Why should I bother with such a trivial vulnerability?"

- TOC/TOU is not in OWASP's Top 10[1]
- It is not even in the CWE's Top 25 Most Dangerous Software Errors[2]

However, that does not make TOCTOU irrelevant. One open (or broken) door is enough for an attacker to break in. That open door doesn't necessarily need to be reflected in the OWASP Top 10 or CWE Top 25.

This guide is exactly about this kind of door. We are talking about time of check to time of use, often abbreviated as TOC/TOU. Unlike cross-site scripting and SQL injection, this door is slightly harder to locate and find. But once open, it can be pretty dangerous.

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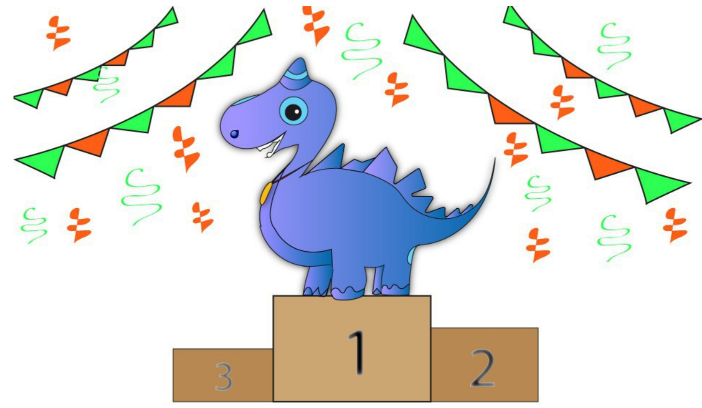
People sometimes refer to TOC/TOU as TOCTOU and TOCTTOU. No matter how you write it, the right pronunciation is "TOCK too."

This guide will walk you through seven TOC/TOU scenarios. Note that the application, OWASP TimeGap Theory, is designed to be vulnerable to TOC/TOU, but not all web applications are vulnerable. There are several methods to safeguard applications from TOCTOU issues. We won't be discussing them here as they are beyond the scope of this handguide. [7]

However, by the end of this guide:

- You will be a TOC/TOU Champion
- You will be equipped with tools and techniques to check if your application is vulnerable to TOCTOU
- You will be able to forecast TOCTOU issues on application by looking at the high-level design in threat-modeling sessions
- You also will be in a position to demonstrate TOCTOU issues to your peers



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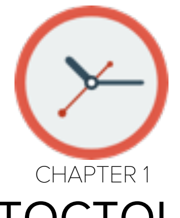

CHAPTER 1

TOCTOU

What are these issues?
How do they become security issues?

From Wikipedia: In software development, time-of-check to time-of-use is a class of software bugs caused by a race condition involving the checking of the state of a part of a system and the use of the results of that check. [3]

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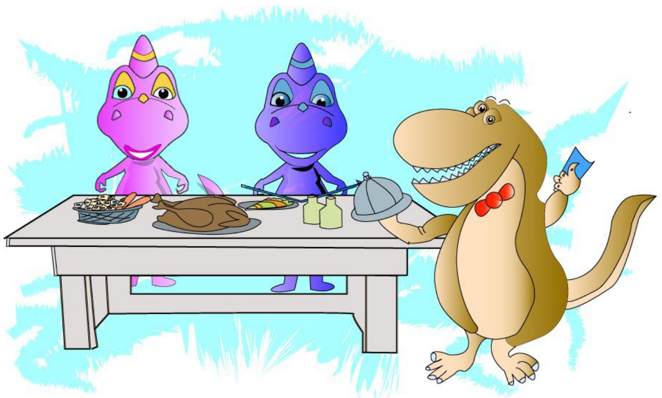
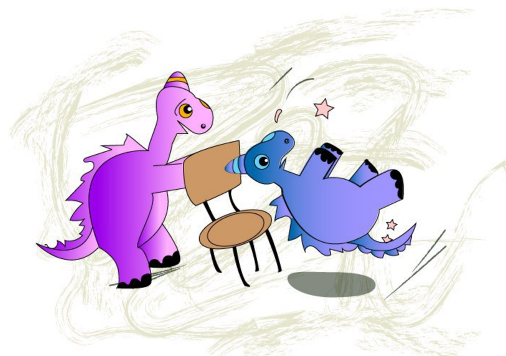


Confused? Let us look at a scenario:

1. Your friends are at a restaurant
2. You joined them late
3. You noticed an empty chair and proceeded to sit there
4. Your friends want to shake hands with you, so you stand up again
5. Meanwhile, one of the friends pulled the chair
6. You proceeded to sit but ended up falling on the floor



There were two threads in the above scenario. One was you, and the other one was your friend. Both of you were accessing the same variable, i.e. the chair. Your friend acted on the variable and made a change. You were not aware of the change and proceeded to sit on the variable - chair.

Let us look at another example:

1. You and your brother are running a mattress store
2. A customer approaches you
3. The customer asks you if they can get two sets of pillows
4. You check if you have enough stock
5. You have exactly two sets of pillows available
6. You bill the customer
7. You go back and find only one set of pillows in stock
8. Your brother already sold one set of pillows to another customer

Do you see where this is going?

1. You did your job
2. Your brother did his job
3. However, both of you did not talk to each other
4. In the end, one customer was unhappy
5. You also were left unhappy which eventually made your brother unhappy

These scenarios can be applied to software development. You think of a problem, write a simple solution, and then deploy this code. During runtime, the code will run in parallel threads, but these threads do not talk to each other. Neither do they share a common state. They often share the same variables (storage units) in memory or in a database. What if one thread modifies these variables while the other thread is still working on it? This can cause concurrency issues.

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In software applications, these concurrency issues can lead to annoying bugs. Sometimes these bugs can turn into bigger security issues. Ultimately, these security issues can lead to major business risks. You might ask yourself how? We will discuss that next in this guide.

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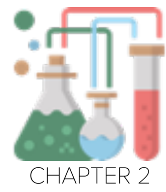
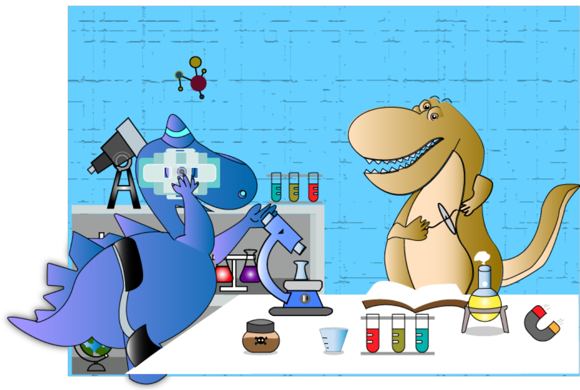


CHAPTER 2

Lab Setup!

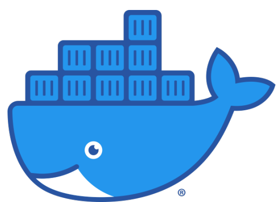
Lab setup is easy!
The entire lab is ready for you to download and run.



First, we need to get to the download and install some software. There are two ways forward:

1. If you're planning to launch tools or scripts against the test instance, set up a local OWASP TimeGap Theory lab
2. If you're planning to perform light-weight testing using a browser, use the online version

Local OWASP TimeGap Theory Lab using Docker



Follow the next steps if you are planning to set up a local OWASP TimeGap Theory lab.

- Approximate time required: 20 minutes
- Budget: $0, no paid software required
- Prerequisite: Windows Pro / Mac / Linux computer

1. Install Docker (the free community edition is okay.)
    a. https://www.docker.com/
    b. https://docs.docker.com/
2. Have at least two browsers installed
    a. Firefox and Chrome work the best
    b. If you have only one browser, you can use an incognito/private window as the other browser
3. Download OWASP TimeGap Theory
    a. Download the ZIP and extract https://github.com/OWASP/TimeGap-Theory/archive/master.zip
    b. Or type in the following in your Terminal:

```
git clone https://github.com/OWASP/TimeGap-Theory.git
```

4. Run Docker
5. Ensure that Docker is running
    a. Run docker -v in your Terminal to check if Docker is up and running. If running, Docker will show you version information.

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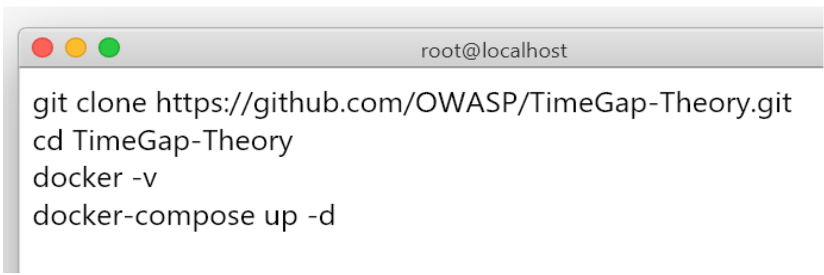
6. Open the command prompt/terminal
7. Change the directory to the OWASP TimeGap Theory directory
8. Run the following command docker-compose up -d



If all works as expected, you should be able to access the following URLs on your browser: http://localhost/

This is the homepage of your OWASP TimeGap Theory Lab.

The fresh installation of OWASP TimeGap Theory won't configure the database automatically. Go to TimeGap Theory > WebApp > Admin and click on the Reset Database button to initialize the database.

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One of the common issues while setting up the Docker lab is getting an error message from CMD/Terminal - “Couldn't connect to Docker daemon. You might need to start Docker”. This means Docker is not running. You can start Docker by launching the Docker application from the Applications/Start menu.

You can also install cURL if you want to try some advanced automation techniques for exploiting TOCTOU vulnerabilities

- If you are using Linux or Mac operating systems, cURL is already installed
- If you are using the latest version of Windows, cURL will also be installed
- If you are using an older version of Windows, you can download cURL from https://curl.haxx.se/windows/

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Online OWASP TimeGap Theory Lab using Heroku

Follow the next steps if you are planning to use the online version of the TimeGap Theory lab.

- Approximate time required: 5 minutes
- Budget: $0, no paid software required

1. Login to your Heroku account at https://id.heroku.com/login
   a. Sign up for a free Heroku account if you do not have one already https://signup.heroku.com
   b. You need to do email verification and add payment information (like credit-card) to the Heroku account for verification purposes.
   c. You won't get charged if you are only running TimeGap-Theory on your Heroku account.
2. Deploy your TimeGap Theory instance
   a. Navigate to https://github.com/OWASP/TimeGap-Theory
   b. Click on the Deploy to Heroku button
   c. Choose a name for your app
   d. Click on Deploy app button
   e. Once deployed, click on View button

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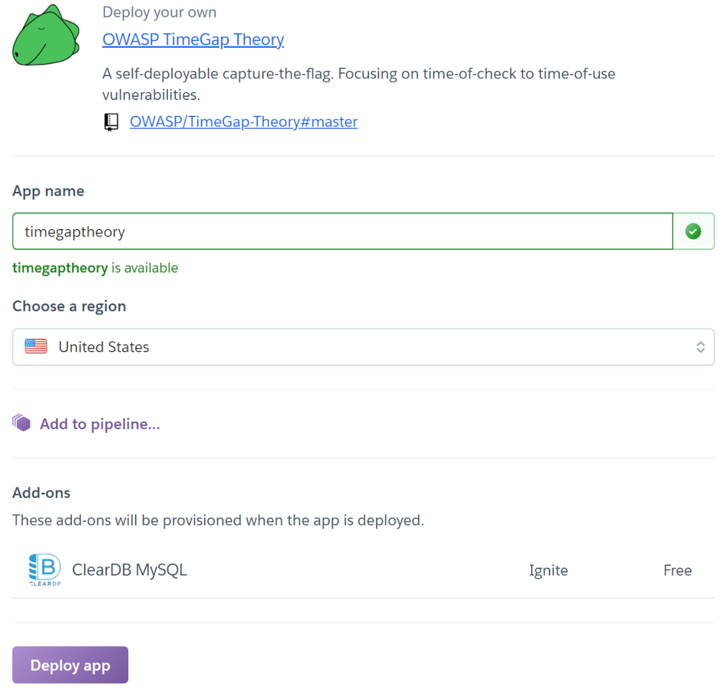

3. Have at least two browsers installed
    a. Firefox and Chrome work the best
    b. If you have only one browser, you can use an incognito/private window as the other browser
4. cURL
    a. If you are using Linux or Mac operating systems, cURL is already installed.
    b. If you are using the latest version of Windows, cURL will also be installed.
    c. If you are using an older version of Windows, you can download cURL from https://curl.haxx.se/windows/

And that's it. You are ready to go.

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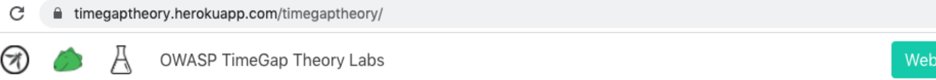

You should be able to see the homepage of your TimeGap Theory Lab.

The fresh installation of OWASP TimeGap Theory won't configure the database automatically. Go to TimeGap Theory > WebApp > Admin and click on the Reset Database button to initialize the database.

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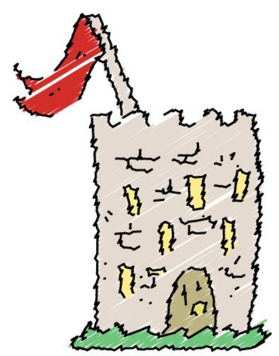
CHAPTER 3

A Quick Refresher!

One more step before the adventure begins.
Let's review how the lab works.



Capture-the-Flag (CTF)

The entire lab is built like a capture-the-flag system. When you solve challenges, you earn points.

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The points distribution is shown below:

Number	Challenge Name	Points
1	Sign Up	100
2	Login	100
3	Transfer	300
4	Mars	200
5	Tickets	100
6	Coupon	100
7	Ratings	100

Total = 1000 points

You do not have to solve these challenges in any particular order. Plus, they are auto-scoring, which means no need for entering flags manually.

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The OWASP TimeGap Theory application directory structure looks like:

OWASP TimeGap Theory

- Score
- Settings
- Webapp
  - Sign Up
  - Login
  - Admin
    - Manage Users
    - Ticket to Mars
    - Reset Database
    - Create default users
  - User
    - Enter coupon
    - Buy tickets
    - Transfer rewards
    - Rate the program
    - Logout

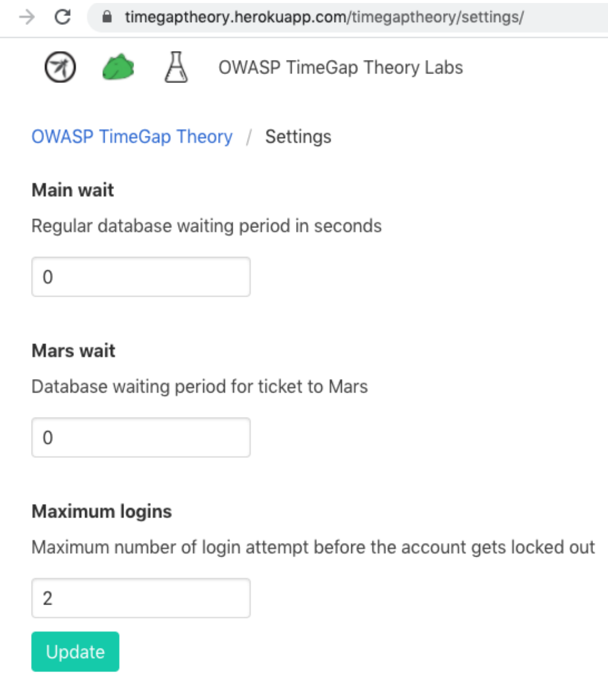
Now, let's look at some of the pages:

Settings

TimeGap Theory > Webapp > Settings

This page allows the configuration of three settings:

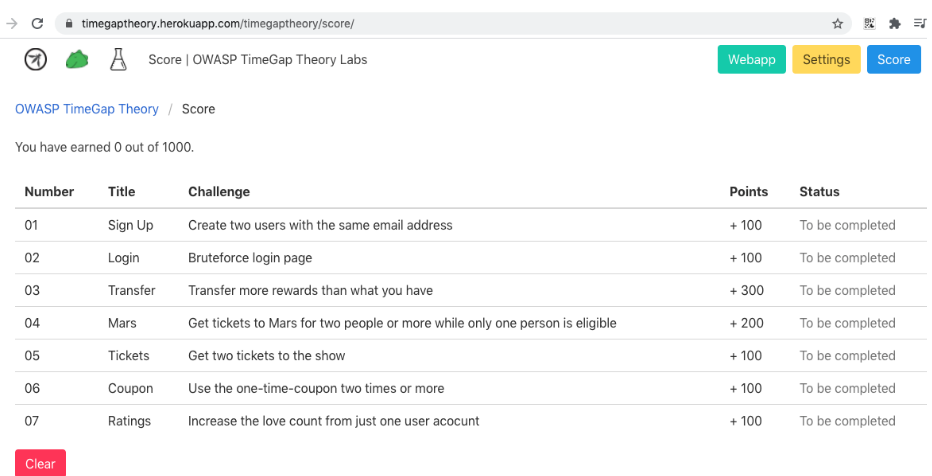
> Main wait - how many seconds the app should wait before it writes to the database
>
> Mars wait - how many seconds the app should wait before it writes to the database on the Ticket to Mars page
>
> Maximum logins - how many times a user can try different passwords before their account gets locked out



Score

TimeGap Theory > Score

You can track your CTF progress here. All the challenges, points, and completion statuses are displayed on this page.



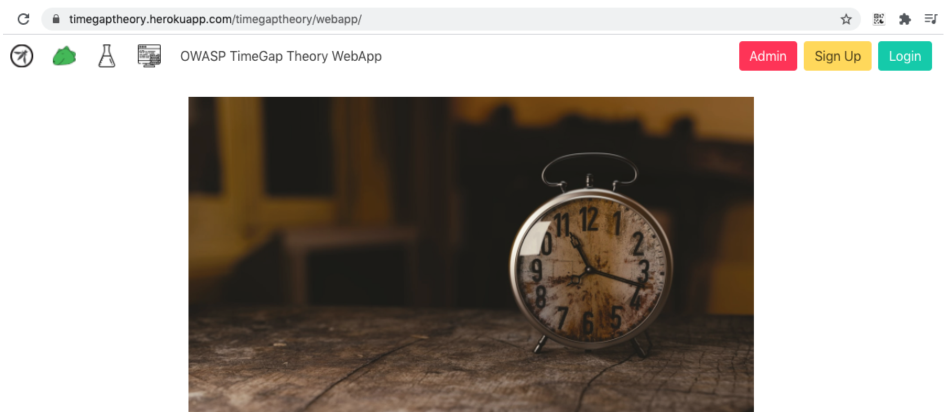
Number	Title	Challenge	Points	Status
01	Sign Up	Create two users with the same email address	+ 100	To be completed
02	Login	Bruteforce login page	+ 100	To be completed
03	Transfer	Transfer more rewards than what you have	+ 300	To be completed
04	Mars	Get tickets to Mars for two people or more while only one person is eligible	+ 200	To be completed
05	Tickets	Get two tickets to the show	+ 100	To be completed
06	Coupon	Use the one-time-coupon two times or more	+ 100	To be completed
07	Ratings	Increase the love count from just one user acocunt	+ 100	To be completed

The clear button at the bottom of the page will clear the progress of all the levels. Use this if you would like to start the lab over again. You can also use it to keep solving the challenges over again and again.

Web App

TimeGap Theory > Webapp

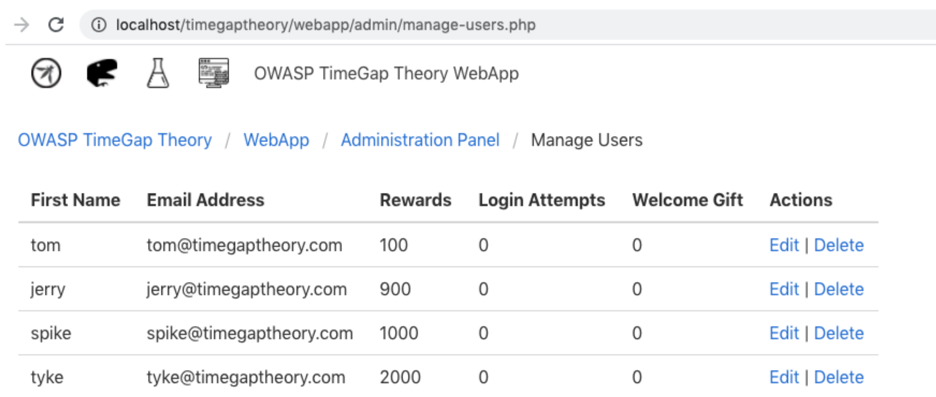
This is your target. Limit all your testing activities to this directory and its subdirectories.



Manage Users

TimeGap Theory > Webapp > Admin > Manage Users

Here you can view, edit, or delete user accounts you have created for TimeGap Theory WebApp.



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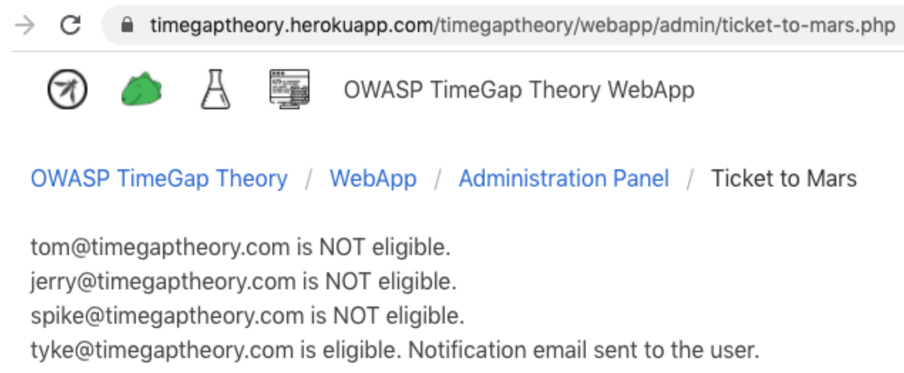
Ticket to Mars

TimeGap Theory > Webapp > Admin > Ticket to Mars

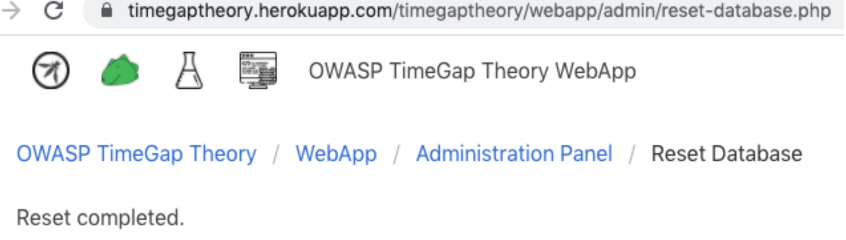
This is the script an admin uses to start the Ticket to Mars program. Once running, the script will go through each user. If the user has at least two-thousand reward points, the script will give them a ticket to Mars. Otherwise, the app will move on to the next user.



Reset Database

TimeGap Theory > Webapp > Admin > Reset database

In case needed, you can reset the database. Doing so will not affect your current score.



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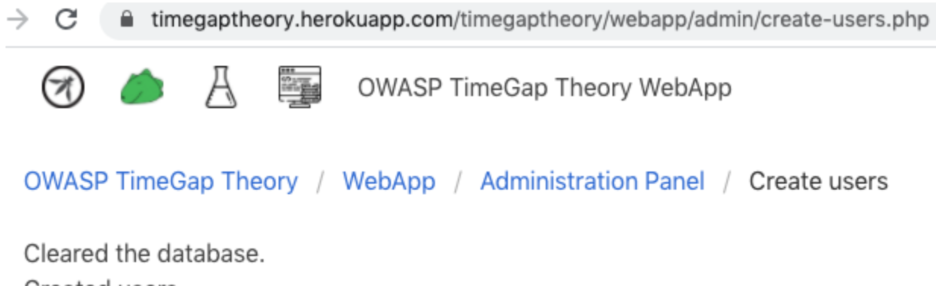
Create Default Users

TimeGap Theory > Webapp > Admin > Create default users

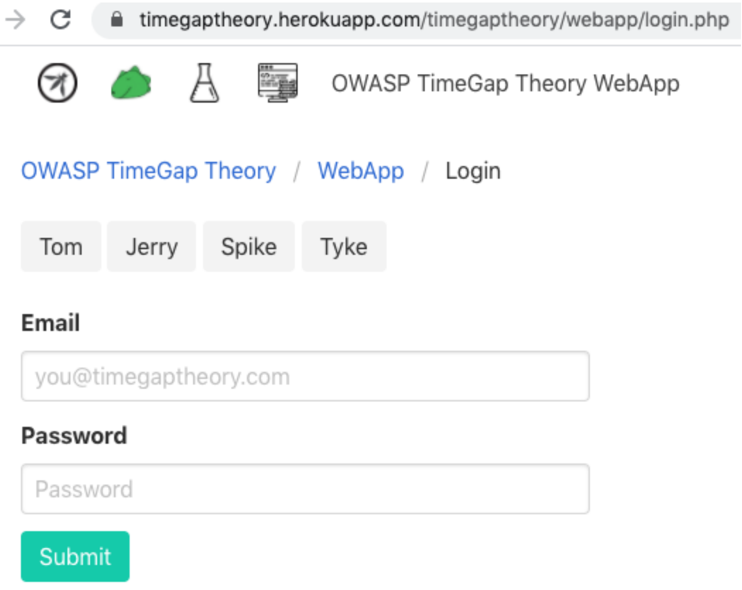
Use this to quickly load the web app with 4 default users: Tom, Jerry, Spike, and Tyke. This saves time from manually creating test accounts through the Sign Up process.



Login

TimeGap Theory > Webapp > Login

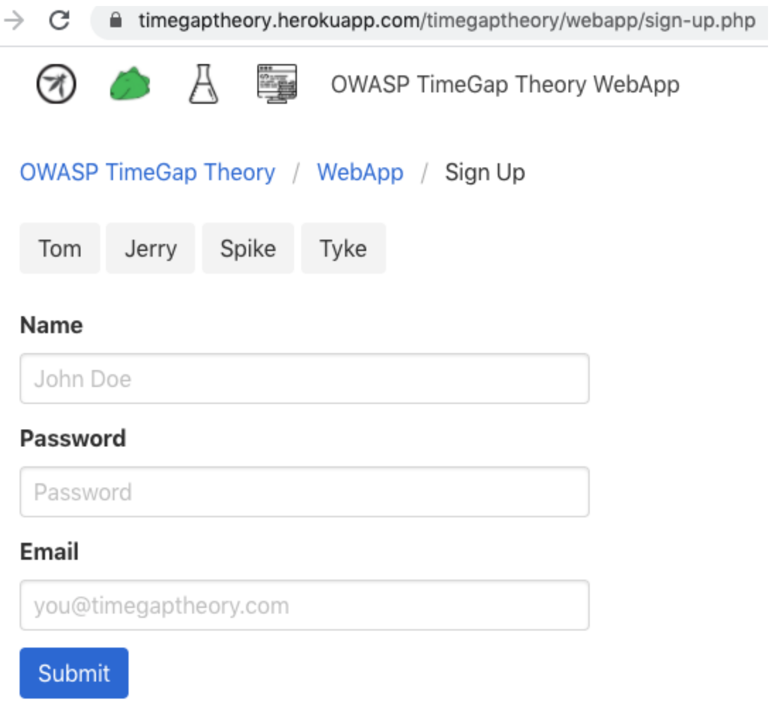
Users can login here. By default, there are no user accounts available on TimeGap Theory. Users must go through Sign Up flow and then login. You can also create users via the Create Default Users option mentioned above.



Sign Up

TimeGap Theory > Webapp > Sign up

Users can sign up for an account here. You need to supply a full name, email address, and a password to create an account.



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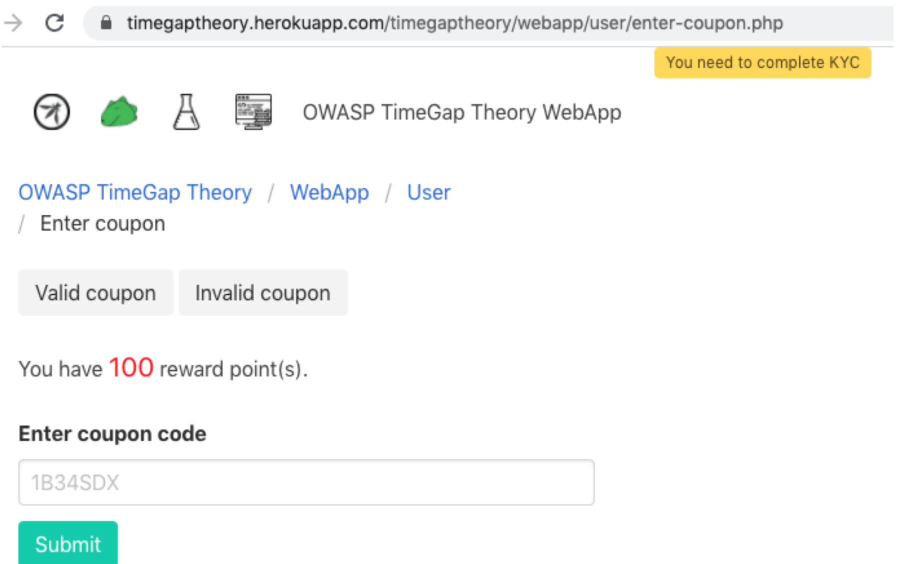
Enter Coupon

TimeGap Theory > Webapp > User > Enter coupon

The application is expecting the following coupon code - WELCOME10. This is a one-time-use coupon. Once entered, it will give the user 200 extra reward points.



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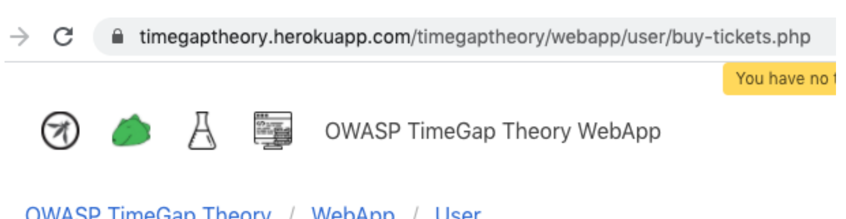
Buy Tickets

TimeGap Theory > Webapp > User > Buy Tickets

Users can buy tickets to the daily show here. The number of show tickets is limited.



OWASP TimeGap Theory / WebApp / User / Buy Tickets

Photo by Kaboompics .com from Pexels

Buy One Ticket

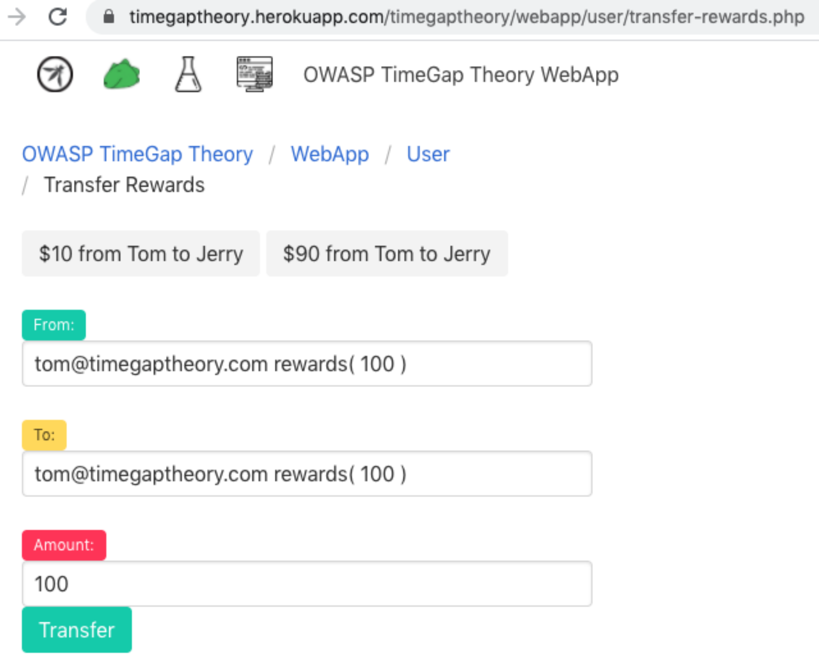
Transfer Rewards

TimeGap Theory > Webapp > User > Transfer Rewards

Users can transfer rewards from their accounts to other accounts here.

There are two rules for each transfer rewards operations:

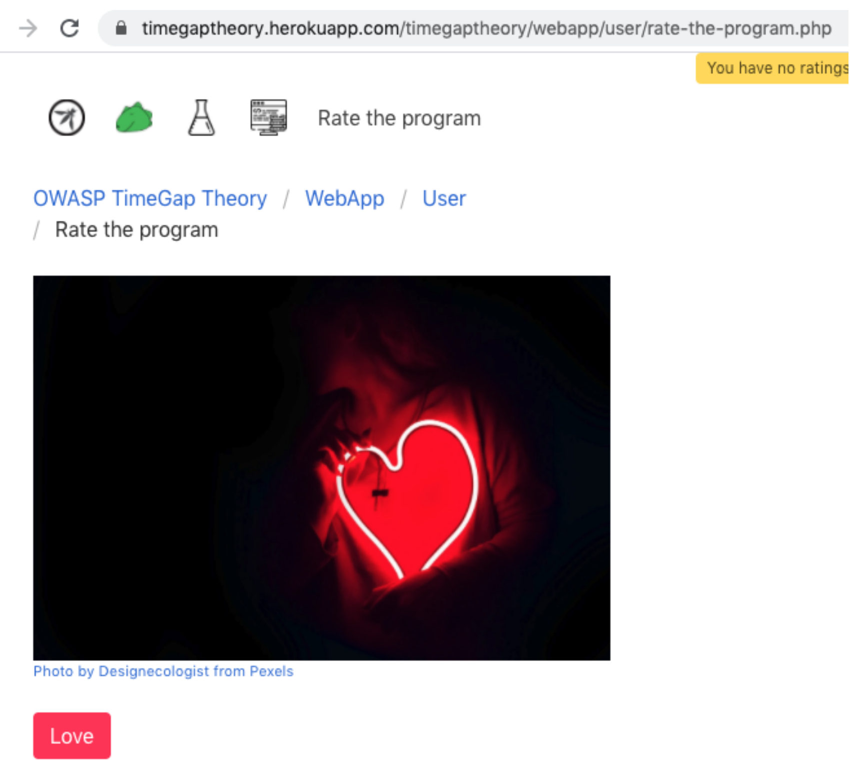
1. From and To accounts cannot be the same. Duh!
2. The balance on the account should be more than or equal to the rewards being transferred.



Rate the Program

TimeGap Theory > Webapp > User > Rate the program

You can rate the show here by clicking on the love button. Only one rating per user is allowed. If you click the love button once again, the app will remove your existing rating.



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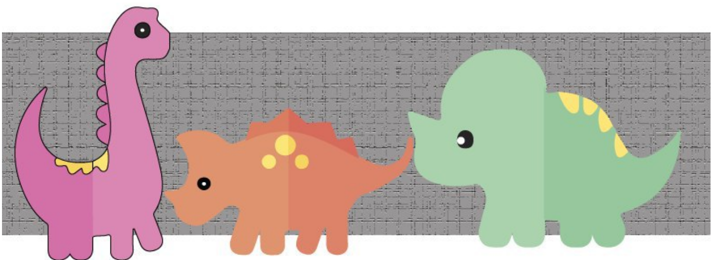
CHAPTER 4

Challenge 1 – Sign Up

Sign up for an account using this page.
Only one account per email ID is allowed.



The sign up pages are pretty common in web apps. The basic functionality of these pages is simple.

- ➔ Users enter their email address and some other details
- ➔ If the email address is not already in the database, the app will create a new account
- ➔ If the email address already exists in the database, the app will show an error

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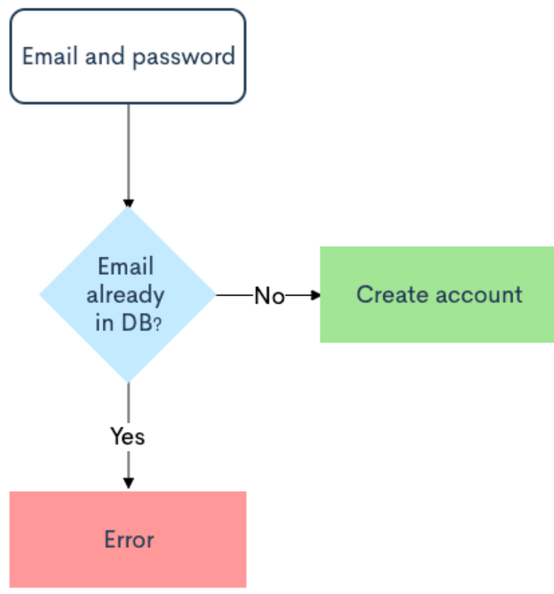
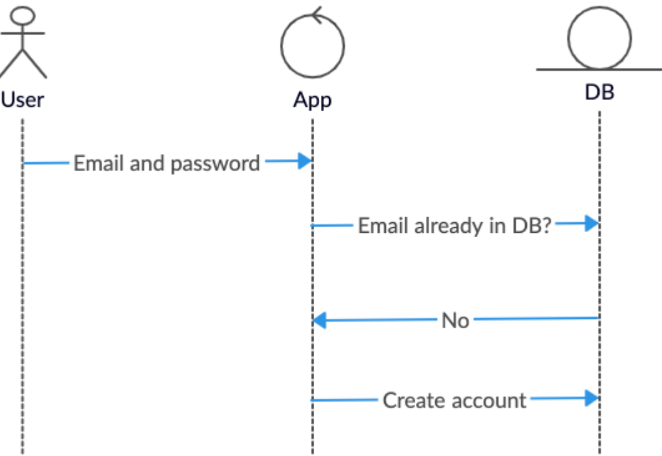


Let us visualize the happy path with the help of a sequence diagram:



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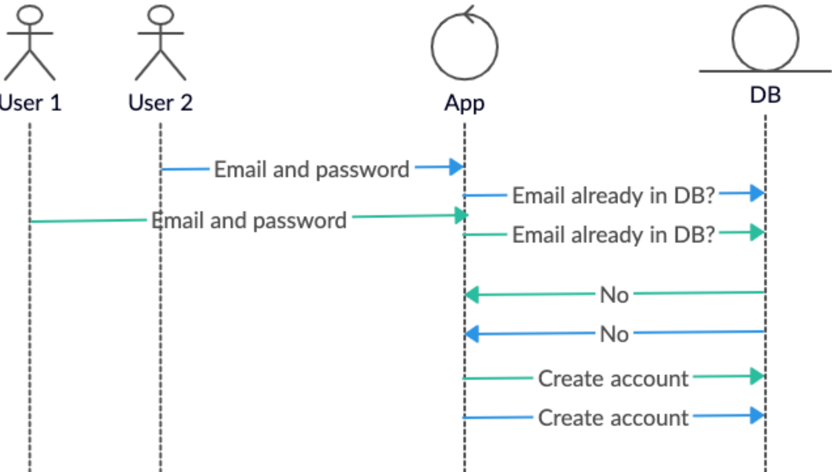
That is the happy path for one user creating an account.

Next, let us reimagine the same scenario, but with two changes:

1. Two users are trying to create user accounts at the same time
2. Both users are trying to sign up with the same email address



The steps at a high level are:

1. Users fill out the Sign up form
2. Both users click on Sign Up at the same time
3. The app will create two threads
4. The threads will each check if the email exists in the database
5. Both threads will get an email does not exist response from the database
6. The app will proceed with account creation
7. Two accounts will be created by the app
8. Both accounts will have the same email address

Well, this looks good in theory, but is it practical? Let us find out.

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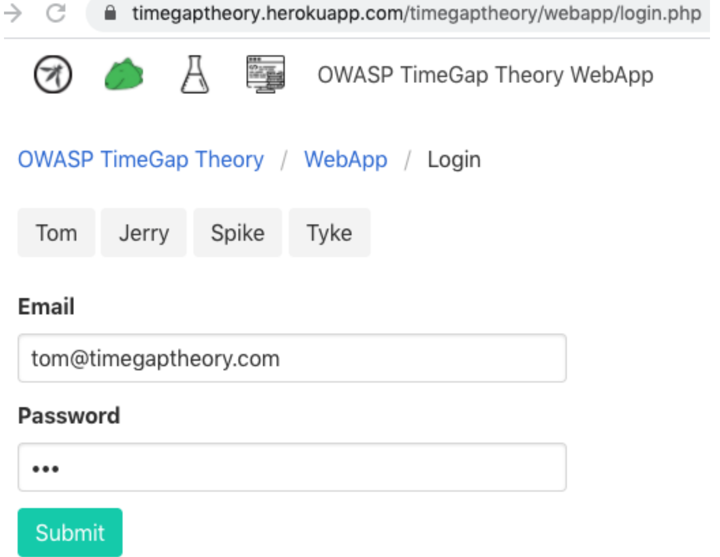
Before getting started with following steps, navigate to Admin > Reset Database page (webapp/admin/reset-database.php)

First, let's go through a regular flow:

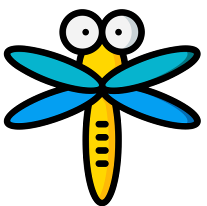
1. Open your browser
2. Navigate to the Sign Up page
3. Click on the first user button - this will fill the form with details of the user Tom
4. Click on the Submit button



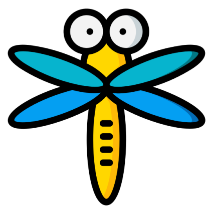
We have created a user account on the system now. We need to see if the app allows us to sign up for another account with the same email. Let us test that by repeating the same steps.

Uh oh! The application does not permit this account creation. However, some time has passed since you created the first account.

First request:



Second request:



We need a way to speed up the sign-up process. We want both the requests to happen more or less at the same time. But how can we do that?

Browser dev tools can be used to send multiple parallel requests to the application in a single go. We can explore that path later. For now, we need another method.

Instead of speeding up the process on our end, we can slow down the app. In real life, attackers achieve this in two ways:

1. By launching distributed denial of service attacks against their target OR
2. By launching their attacks during peak traffic periods

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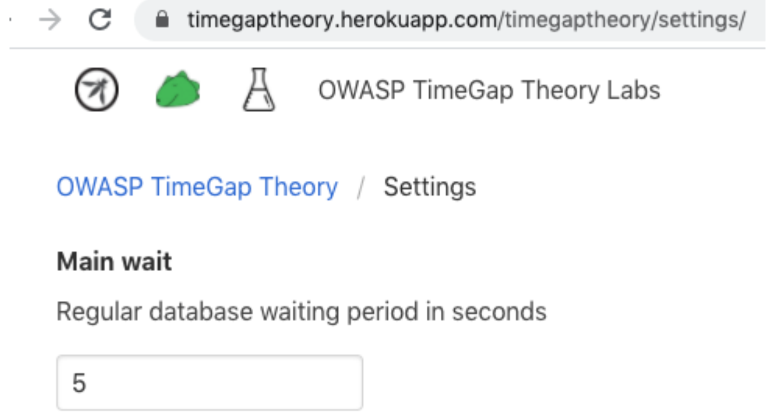
Thankfully, we do not have to do that. TimeGap theory will do that for us.

1. On your browser, navigate to the Settings page of OWASP TimeGap Theory
2. Change the Main wait to 5 seconds
3. Click on the Update button

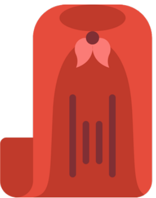


This will make TimeGap Theory wait 5 seconds before every modification operation. If you try to perform anything that requires writing to the database, you will see that it's loading slowly.

5 seconds is more than enough time for us to try out the attack scenario. We need to fire two sign-up flows within 5 seconds time and that requires some preparation.

Preparation Phase

1. Open two browsers side by side (Use private/incognito window if you do not have two browsers)
2. On both the browsers:
    a. Navigate to the Sign up page
    b. Click on the second user button this time - this will fill the form with details of the user Jerry



Alright, the preparation is done. Here comes the exploitation phase.

Exploitation Phase

1. Click on the Submit button on the first browser
2. In the second browser, click the Submit button within the five seconds window

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Post-exploitation phase

1. Wait for both the browsers to complete the request
2. You should see both browsers complete the requests without any errors
3. On one of the browsers, navigate to the Manage Users page
4. Boom! You should have two user accounts with the same email address
5. If you check your score, you should also see you now have 100 points
6. Before moving on, revert the delay back to 0 on the Settings page

Yes, we hear you. This attack technique is not realistic. There is no way you can ask web apps to act slowly in the real world. Launching a distributed denial of service attack is also not reliable. So, what can you do in the real world? If you can't slow down the target, you need to speed up. No, we do not mean clicking on multiple browsers at the same time. You need to automate this part.

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Browser Dev Tools

We love browser dev tools. They are useful for performing some quick security tests. These quick tests include TOC/TOU as well. [4]

First, we need a valid fetch request:

1. Open your browser (Chrome or Firefox)
2. Navigate to the Sign up page
3. Click on any of the user button
4. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
5. On the Sign up page, click on the Sign Up button
6. On the browser dev tools, click on the Network tab
7. Right-click on the sign-up.php request
8. Click on Copy > Copy as fetch

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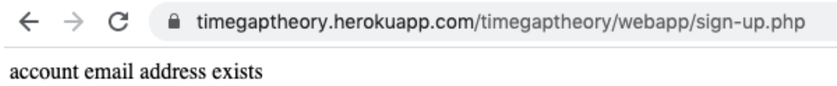
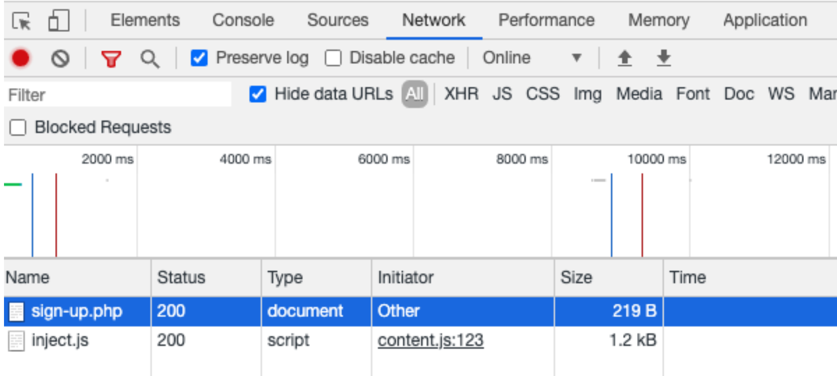




Paste this in the Console tab of the browser dev tools. It should look like the following:

Elements Console Sources Network Performance Memory Applicat

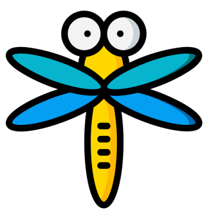
top Filter Default levels

```
> fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/sign-up.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "firstname=tom&password=tom&email=tom%40timegaptheory.com",
    "method": "POST"
  });
```

You may see a slightly bigger fetch request. This is because of the additional headers and request parameters added by the browser. These are optional. The above example shows the bare minimum fetch request.

But that’s just one request.

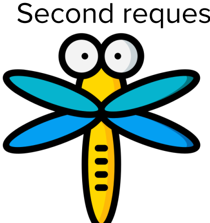
The only request:



We need two parallel fetch requests.

First request:

Second request:



This can be done by copying and pasting the fetch request without pressing the Enter key.

```
Elements  Console  Sources  Network  Performance  Memory  Application
top  ▼  Filter  Default levels ▼

> fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/sign-up.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "firstname=tom&password=tom&email=tom%40timegaptheory.com",
    "method": "POST"
  });fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/sign-up.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "firstname=tom&password=tom&email=tom%40timegaptheory.com",
    "method": "POST"
  });
```

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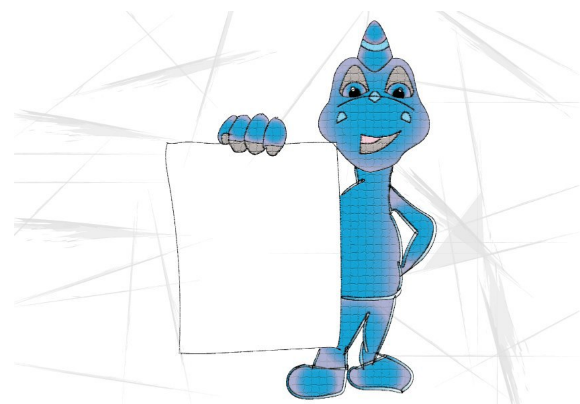
Before running this new command, we need to clear the slate. It involves three simple steps:

1. Ensure that there is no delay
    a. Go to TimeGap Theory > Settings
    b. Check that Main wait is set to 0
2. Delete any existing Tom user
    a. Go to TimeGap Theory > Admin > Manage Users
    b. Delete the user Tom
3. Clear your current score
    a. Go to TimeGap Theory > Score
    b. Click on the Clear button



Alright, our slate is clear. Let us execute the attack now:

1. Enter the combined fetch requests on the Console tab of browser dev tools
2. Press the Enter key
3. Go to TimeGap Theory > Admin > Manage Users
4. See if two users with the same email address are created
5. Go to TimeGap Theory > Score
6. Check if you got points for completing the Sign Up challenge

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timegaptheory.herokuapp.com/timegaptheory/webapp/admin/manage-users.php

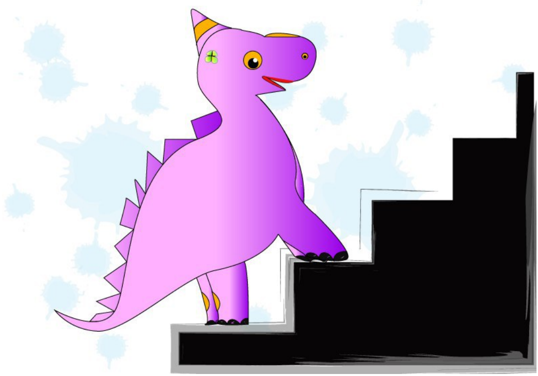
OWASP TimeGap Theory WebApp

OWASP TimeGap Theory / WebApp / Administration Panel / Ma

First Name	Email Address	Rewards	Login Atte
tom	tom@timegaptheory.com	100	0
tom	tom@timegaptheory.com	100	0

What would be the business impact of such an attack? Depending on how the app is designed, there are several possibilities:

- A legitimate user may try to register for their account in the future
- They may also get several emails asking them to confirm the account creation
- If a legitimate user confirms the account, the attacker may get a permanent backdoor to the user account
- Attackers would be able to carry out any actions on the app with all the audit trails pointing out to the legitimate user



Let's summarize what we completed:

1. The Sign up page allows only one user account per email address
2. You ensured the business logic is working under normal scenarios
3. You slowed down the system and bypassed the business logic
4. You bypassed the business logic by using a tool that makes concurrent requests
5. Now you know how TOC/TOU security issues work and how to exploit them

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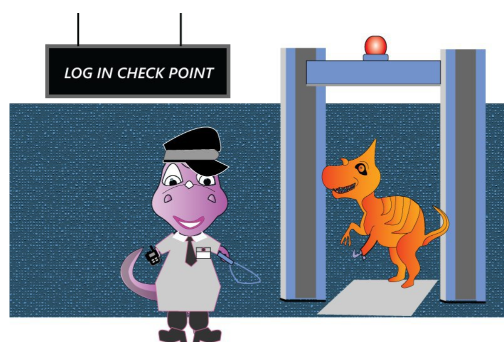
CHAPTER 5

Challenge 2 – Login

The starting point for all users.
Rate limited to avoid brute force attacks.



Login pages are the user's starting point in many web apps. They collect username/email and password and create user sessions if they are valid.

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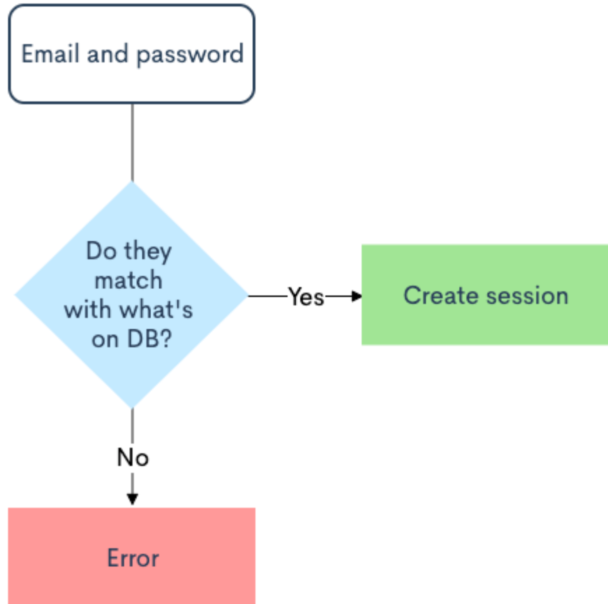
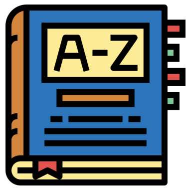
Let us look at a sample login page flow:



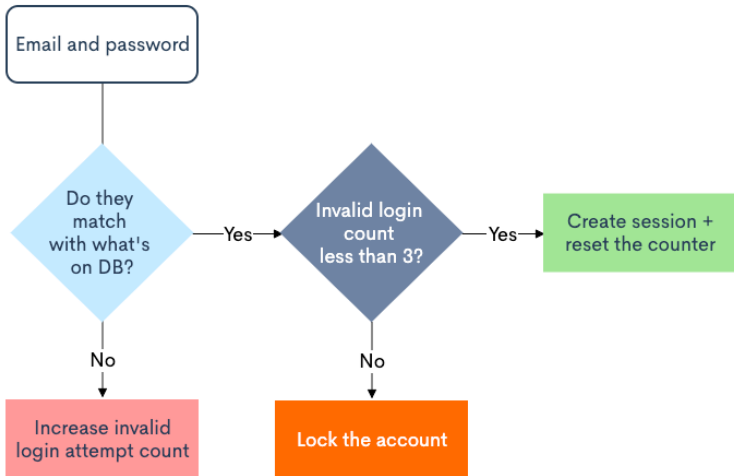
There is an obvious flaw here. Let us review it:

1. Tom is an attacker
2. Tom wants to break into Jerry's account
3. Tom tries jerry@abcd.com, jerry@efgh.com, etc
4. Tom gets account does not exist error
5. Tom tries jerry@example.com
6. Tom gets invalid password error. This means there is a user account with jerry@example.com as user name
7. Tom tries logging into the portal with jerry@example.com and 1,2,3,a,b,c etc. as the password
8. Tom gets invalid password error for all of them
9. Then Tom tries jerry as the password and Boom! Tom just logged in to the portal as Jerry



The above scenario is a major headache for all login pages. These types of attacks are known as dictionary or brute force attacks. There are multiple ways to protect login pages from brute force attacks - captchas, delays, account lockouts, generic error messages etc.

What happens if we revise the current login page design with account lockouts. If the user is not able to login successfully within a few tries, the portal will lock the user's account.



As you can see, the account lockout is achieved by storing the number of failed login attempts on the server side. For every failed login attempt, the app will increment the counter. If the value exceeds a certain point, for example 3, the portal will lock the account.

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The high-level steps are:

1. User enters the correct username but the wrong password.
2. Portal increases the failed login attempt count to 1.
3. User enters the wrong password again.
4. Portal increases the failed login attempt count to 2.
5. User enters the wrong password one more time.
6. Failed login attempt count reaches 3.
7. The portal locks out the user out of their account.

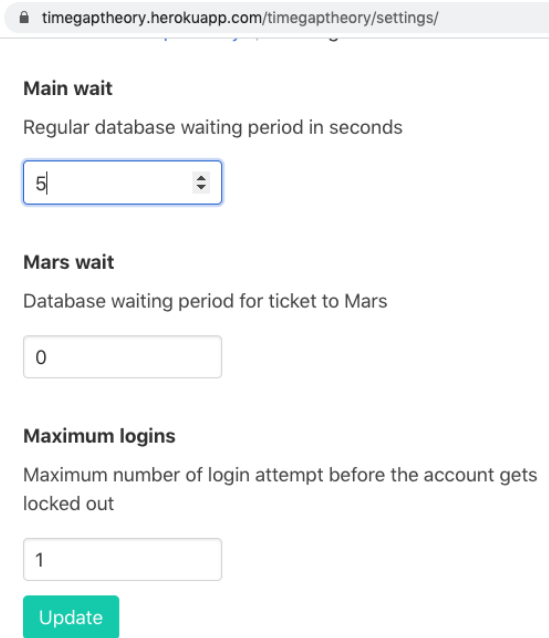
Sounds good? Let us verify this in our lab:

1. Open your browser
2. Navigate to the login page
3. Enter tom@example.com as the username
4. Enter abcd as the password
5. Click on the Login button a few times
6. Initially, you will get an error message that goes Login failed
7. After a few tries, you will see a different error message - Your account is locked out
8. You have been locked out of the user account
9. Now, change the password from abcd to tom
10. Click on the login button again
11. The system will not allow you to login even with the correct password because the account is locked

What if we perform all these login attempts in a single try before the server updates the failed login attempt counter on the database? Let us check that theory.

By default, TimeGap Theory will lock the user account on the third wrong attempt. In order to successfully test our attack, we would need more than three browser windows. That kind of spoils the fun, doesn't it? Let us reduce the maximum failed attempt to 1. This way, we just need two browser windows to test.

1. On your browser, navigate to the Settings page
2. Change the login attempt count to 1
3. Click on the Save button
4. Stay on the Settings page, we need to do one more thing



Time to slow down TimeGap Theory:

1. Change the Main wait to 5 seconds
2. Click on the Save button

Now, TimeGap Theory will wait 5 seconds before every database write operation. This write operation includes failed login attempts values.

Preparation Phase

1. Open two browsers side by side (Use a private/incognito window if you do not have two browsers).
2. On both the browsers:
    a. Navigate to the login page
    b. Click on the second user button this time - this will fill the form with details of the user Jerry

Alright, the preparation is done. Here comes the exploitation phase.

Exploitation Phase

1. Click on the Login button on the first browser
2. In the second browser quickly also click on the Login button

Post-exploitation Phase

1. Wait for both the browsers to complete the request
2. You should see the login attempt was successful on the second browser
3. Check the user login attempt count is greater than 1. Phew
4. If you check your score, you should see you have 100 points
5. Before moving on, revert the delay to 0 on the settings page

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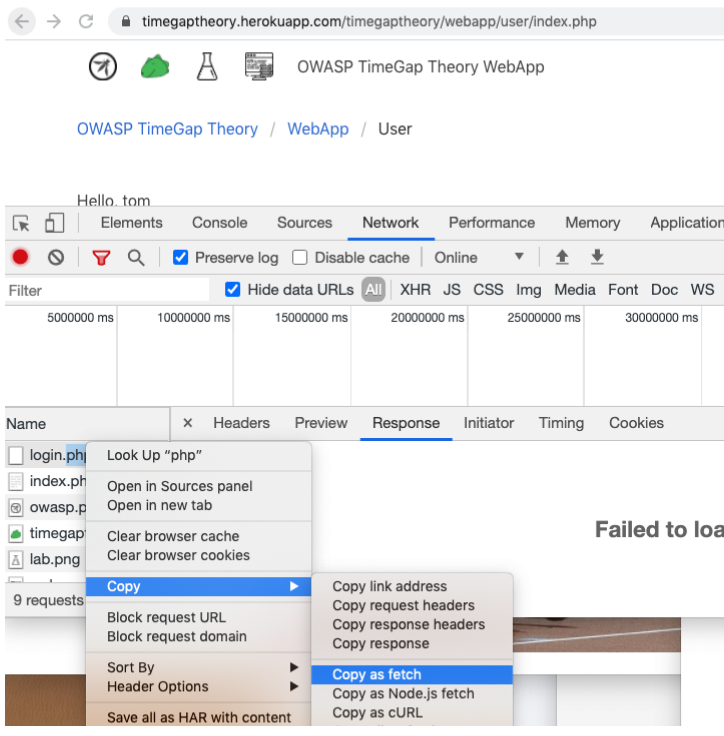
Automation Time

There is no way we can perform a brute force attack like this in real life. You cannot call the webmaster and ask them to delay the server. Browser Dev Tools to the rescue again.

First, we need a valid fetch request:

1. Open your browser (Chrome or Firefox)
2. Navigate to the login page
3. Click on any of the user buttons
4. Open up dev tools by pressing F12 on the browser
   a. On Windows, you can use Ctrl + Shift + I
   b. On Mac, you can use Cmd + Shift + I
5. On the login page, click on the Submit button
6. On the browser dev tools, click on the Network tab
7. Right click on the login.php request
8. Click on Copy > Copy as fetch



Paste this in the Console tab of the browser dev tools. It should like the following:

```
Hello, tom
Elements   Console   Sources   Network   Performance   Memory   Appli
top   Filter   Default levels
> fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/login.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "email=tom%40timegaptheory.com&password=tom&submit=Submit",
    "method": "POST",
    "mode": "cors"
  });
```

It is okay if you see a request with some more elements. We trimmed down the unwanted portions to make it look clean.

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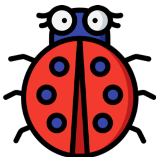
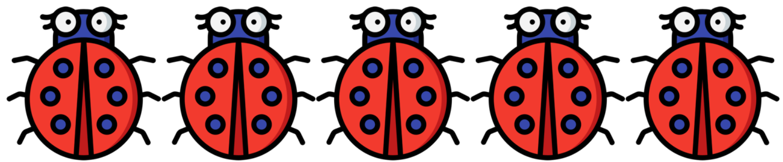
But that's just one request.



We are talking about brute forcing here. We need a minimum of 5 for this simulation.



Copy and paste the fetch request without pressing the Enter key. However, it is a good practice to separate each request with a comma. Let us do that.

Elements Console Sources Network Performance Memory Applica

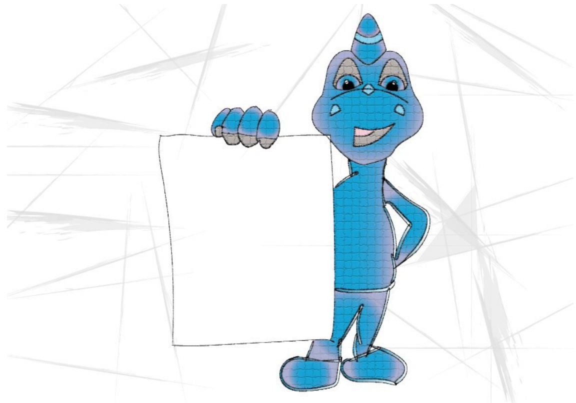
top Filter Default levels

```
fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/login.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": "email=tom%40timegaptheory.com&password=tom1&submit=Submit",
  "method": "POST",
  "mode": "cors"
}),fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/login.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": "email=tom%40timegaptheory.com&password=tom3&submit=Submit",
  "method": "POST",
  "mode": "cors"
}),fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/login.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": "email=tom%40timegaptheory.com&password=tom2&submit=Submit",
  "method": "POST",
  "mode": "cors"
}),fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/login.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": "email=tom%40timegaptheory.com&password=tom&submit=Submit",
  "method": "POST",
  "mode": "cors"
});
```

We also changed the password value in each request. The first four requests have the wrong password. The last request has the correct password.

Before running this new command, we need to clear the slate. It involves three simple steps:

1. Ensure that there is no delay
    a. Go to TimeGap Theory > Settings
    b. Set the Main wait to 0
2. Refresh the user accounts.
    a. Go to TimeGap Theory > Admin
    b. Click on Create Default Users
3. Clear your current score.
    a. Go to TimeGap Theory > Score
    b. Click on the Clear button



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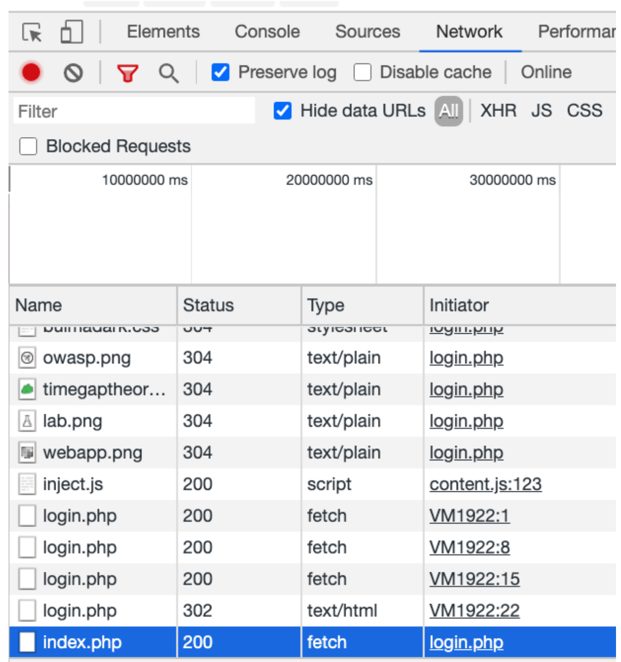
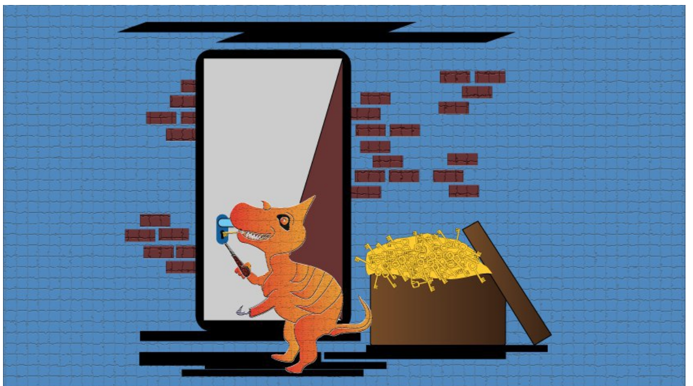
Alright, our slate is clear. Let us execute the attack now:

1. Enter the combined fetch requests on the Console tab of browser dev tools
2. Press the Enter key
3. Go to the Network tab of the browser
4. See if you can find an index.php file
5. Right click on it and select open in a new tab
6. You are logged in
7. If you want to see which password was correct, you can check which request showed true in the Console tab
8. Go to TimeGap Theory > Score
9. You should have got 100 points for completing the Login challenge



What is the business impact of such an attack? Depending on how the app is designed, there are several possibilities:

1. A legitimate user may keep getting their account compromised despite changing their passwords
2. Attackers may compromise the admin functionalities of web apps



Let us summarize what we completed:

1. The login page rate limits the login attempts by locking the account
2. You analyzed this behavior by locking out one account
3. You slowed down the system and bypassed the business logic
4. You bypassed the business logic by using browser dev tools
5. Now you know how TOC/TOU security issues can affect login pages

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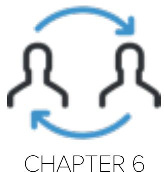
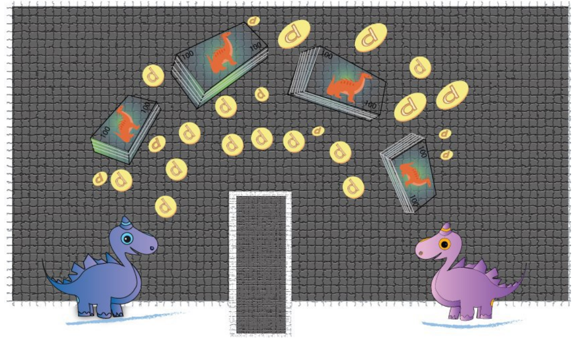


CHAPTER 6

Challenge 3 – Transfer

Transfer reward points between users.



Transferring rewards is not something we do every day. But sending money is. Think of the transfer rewards as sending money. The basic functionality is identical.

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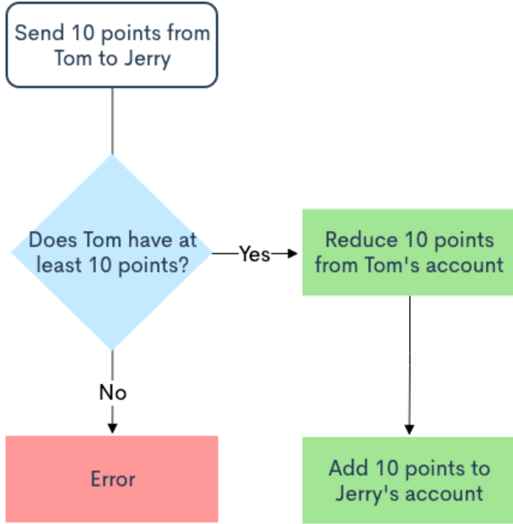
Let us look at a sample transfer rewards flow:



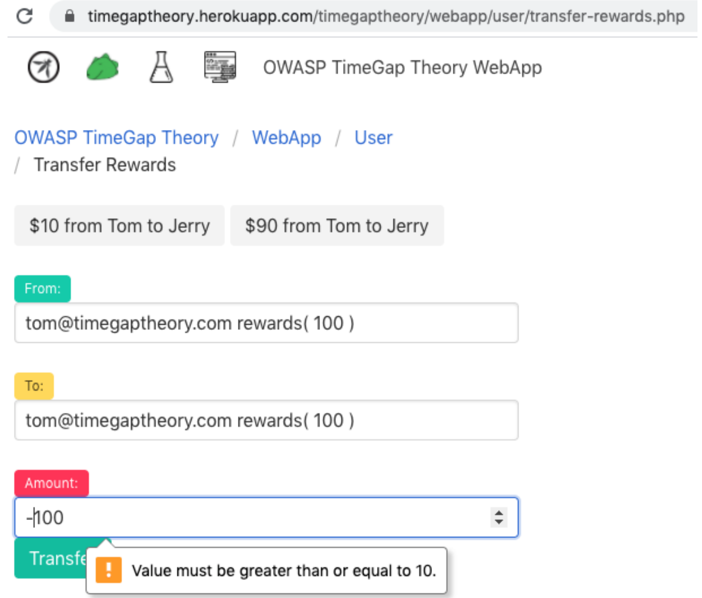
There are three conditions to be met for the transaction to be successful:

1. Transaction amount should be a positive number
2. Payer and payee can not be same
3. Payers should have enough balance in their account

Let us see if the application is performing those checks. Go to the Sign up page and create two user accounts - Tom and Jerry

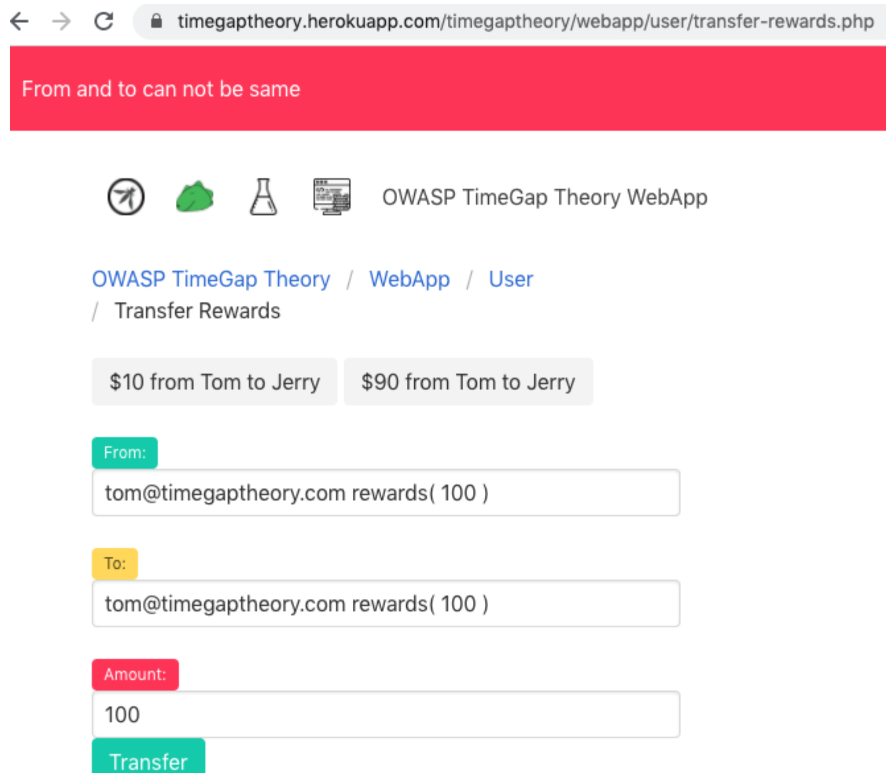
Transaction amount should be a positive number:

1. Go to the Transfer page
2. Put in a negative number in the amount field
3. Click on the Transfer button



Payer and payee can not be same:

1. Go to the Transfer page
2. Select the same user as payer and payee
3. Put in a 10 as the amount
4. Click on the Transfer button



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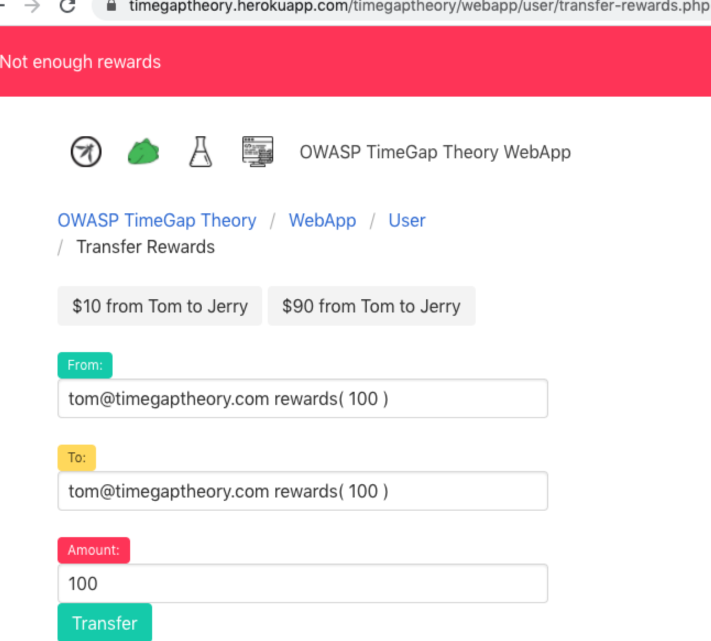
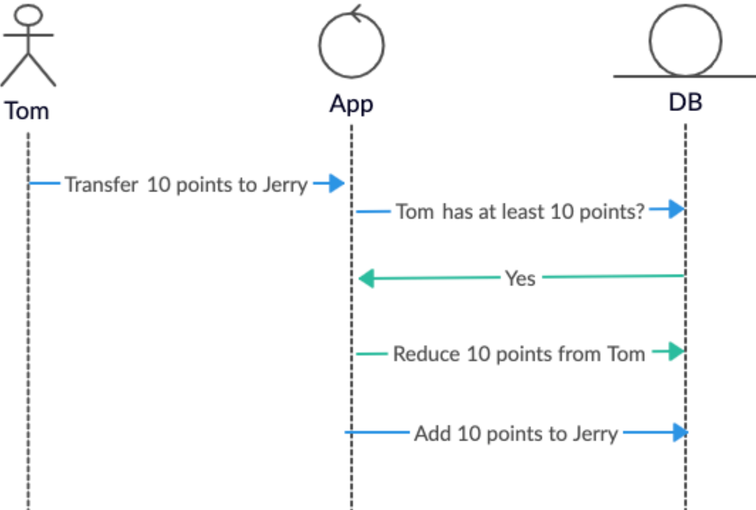
Payer should have enough balance in their account:

1. Go to the Transfer page
2. Select a payer and payee
3. Put in a 300 as the amount
4. Click on the Transfer button



Let us visualize the happy path with the help of a sequence diagram:



Our aim is to bypass the business logic and send more reward amounts than we have. How can we do that? We need to make multiple transactions before the application deducts it from the balance.

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It’s time to slow down TimeGap Theory:

1. On your browser, navigate to the Settings page
2. Change the time delay to 5 seconds
3. Click on the Save button

Now, TimeGap Theory will wait 5 seconds before every database write operation.

Preparation phase

1. Open two browsers side by side (Use private/incognito window if you do not have two browsers)
2. On both the browsers:
    a. Navigate to the Login page
    b. Click on the first user button - this will fill the form with details of the user Tom
    c. Navigate to the Transfer rewards page
    d. If the account has 100 points as balance, put a lesser amount as the transfer value on both the browsers. Say, 90
    e. Select Tom as the payer
    f. Select Jerry as the payee
    g. Note down the balance on Jerry’s account (which is displayed in simple bracket)

Alright, the preparation is done. Here comes the exploitation phase.

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Exploitation phase

1. Click on the Transfer button on the first browser
2. Go to the second browser as fast as you can
3. Click on the Transfer button on the second browser

There comes our third and final phase:

Post-exploitation phase

1. Let us wait for both the browsers to complete the request
2. You can see that the transfer operations were successful on both the browsers
3. Check the balance of user Jerry
4. Phew. You transferred more points from Tom’s account that what they had
5. If you check your scores, you will see that you have got 100 points for transfer challenge
6. Don't forget to change the delay to back to 0 on the Settings page

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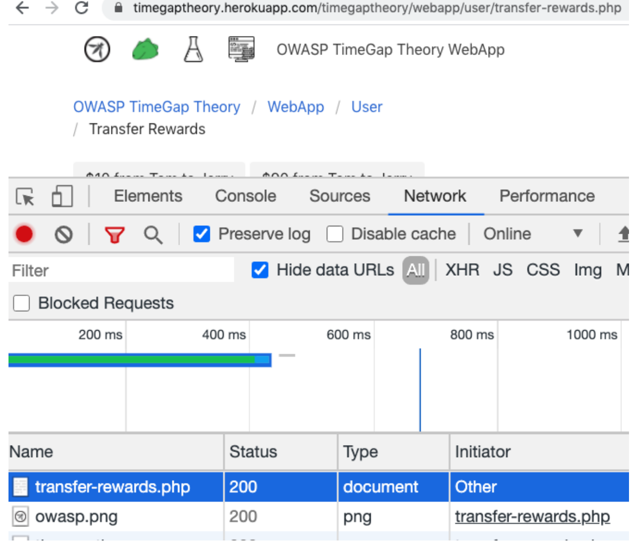
Automation time

Let's try and automate this.

First, we need a valid fetch request:

1. Open your browser (Chrome or Firefox)
2. Navigate to TimeGap Theory > Login
3. Click on the first user button. This will fill the user details for user Tom
4. Click on the login button
5. Navigate to TimeGap Theory > Webapp > User > Transfer rewards
6. Click on the first $10 from Tom to Jerry button. This will fill the form with some transfer details.
7. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
8. Click on the Transfer button
9. On the browser dev tools, click on the Network tab
10. Right click on the transfer-rewards.php request
11. Click on Copy > Copy as fetch



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Paste that on the Console tab of the browser dev tools. You will get something like the following:

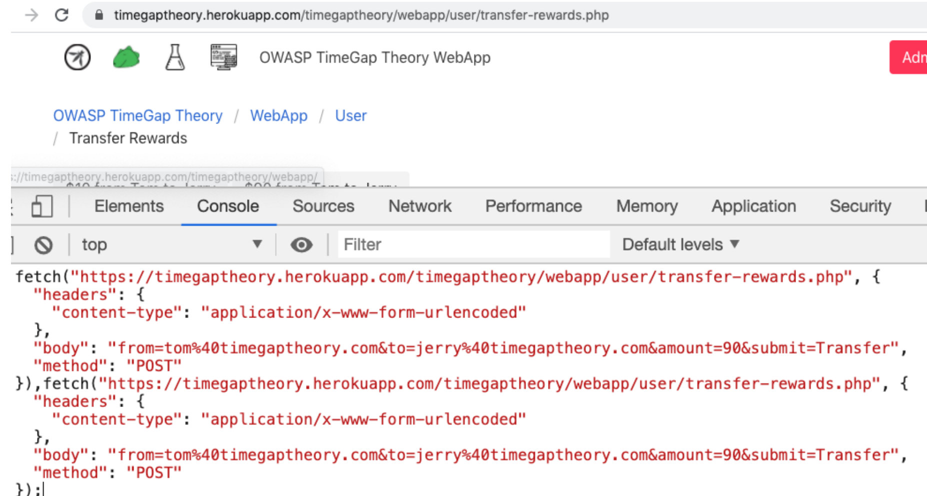
```
fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/transfer-rewards.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": "from=tom%40timegaptheory.com&to=jerry%40timegaptheory.com&amount=90&submit=Transfer",
  "method": "POST"
});
```

Again, don't worry if you see a slightly bigger request. That is just your browser being naughty. You can use that request as it is, or use the one shown above.

Now we have a request.

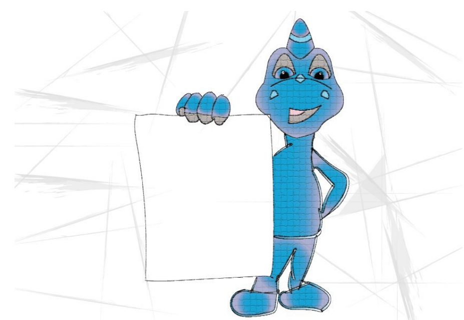
And we need two requests.

It can be done by copy-pasting the fetch request without pressing the Enter key. However, it’s a good practice to separate each request with a comma. Let us do that



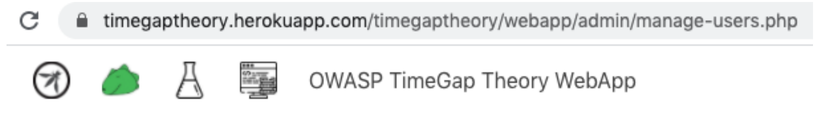
Before running this new command, we need to clear the slate. It involves two simple steps:

1. Ensure that there is no delay
    a. Go to TimeGap Theory > Settings
    b. Ensure that the Main wait is set to 0
2. Clear the current score
    a. Go to TimeGap Theory > Score
    b. Click on the Clear button



Alright, our slate is clear. Let us execute the attack now:

1. Enter the combined fetch requests on the Console tab of browser dev tools
2. Click on the To field to see the rewards on each account
3. Now you see a negative value in Tom's account
4. You also see corresponding change in Jerry's account
5. Go to TimeGap Theory > Score
6. Check if you got points for completing the Transfer rewards challenge



OWASP TimeGap Theory / WebApp / Administration Panel / Manage Users

First Name	Email Address	Rewards	Login Attempts	Wel
tom	tom@timegaptheory.com	-80	0	0
jerry	jerry@timegaptheory.com	1080	0	0
spike	spike@timegaptheory.com	1000	0	0
tyke	tyke@timegaptheory.com	2000	0	0

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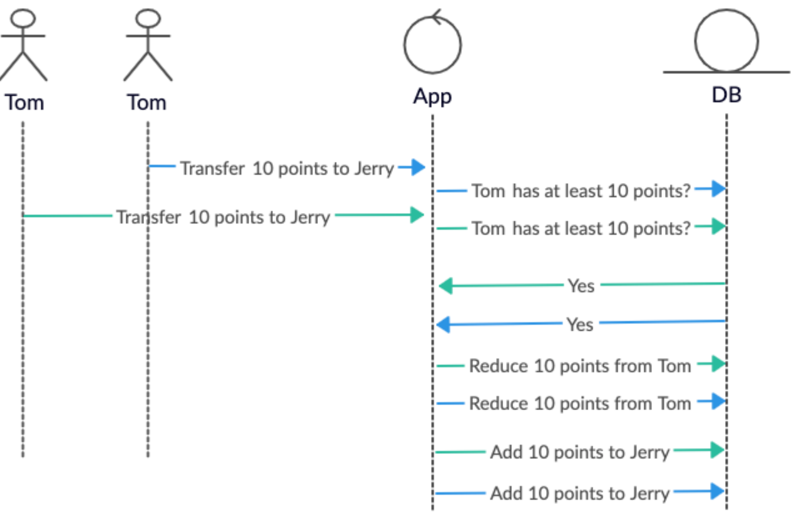
What would be the business impact of such an attack? Depending on how the app is designed, there are several possibilities:

1. A user may start a huge number of parallel requests. They may transfer this boat load of money/points to an account controlled by them or by their friends/relatives
2. Attacker may work with friends to perform these transactions back and forth infinite amount of times



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Let us review what we did:

1. The transfer rewards page is performing basic checks to prevent abuse
2. One of these checks includes checking the payer's account to see if they have sufficient balance
3. You analyzed this behavior by trying to transfer more points than what you have in balance
4. First, you slowed down the system and bypassed the business logic
5. Then you bypassed the business logic by using browser dev tools
6. You must have noticed during the automation phase that accessing the transfer-rewards page does not require authentication.
    a. If you manually enter the transfer-rewards page URL on your browser, you will be able to access this page without logging in first
    b. This made the TOCTOU exploitation slightly easy. No need to worry. In upcoming chapters, you will learn how to exploit TOCTOU issues in authenticated pages as well.
7. Now you know how TOC/TOU security issues can affect money/points transfer pages

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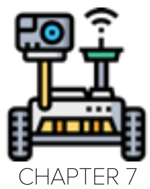
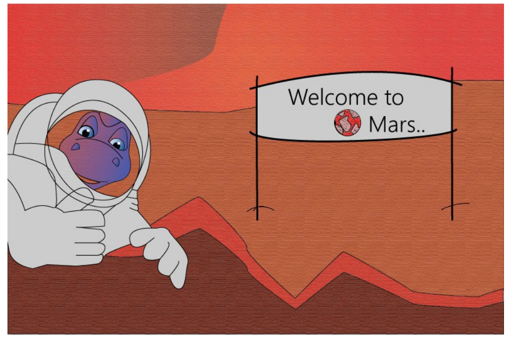


CHAPTER 7

Challenge 4 – Mars

Get tickets to Mars.
Explore the possibilities.



Flying to Mars? We haven't seen such a possibility so far. We have something similar though - flying to Paris.

Despite the name, the basic functionality is simple. The page is run by admins or an automated script. Once run, it will go through each user account. If the user has more than 2000 reward points, the page will send a ticket to the user.

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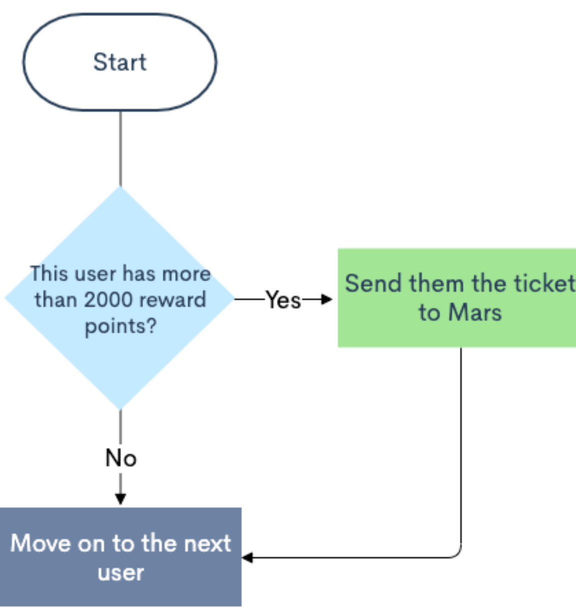
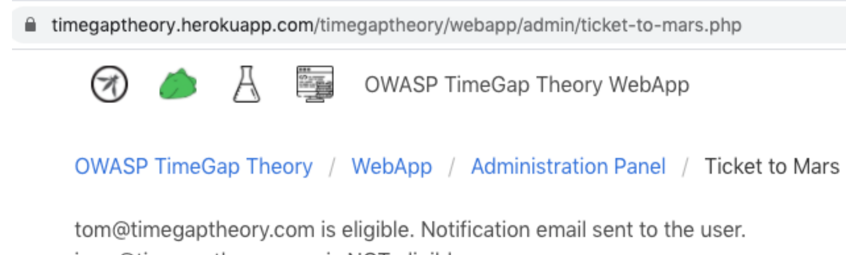
Let us visualize that:



There is only one condition to be met for a user to earn the ticket - their account should have more than 2000 points at the point of check.

Let us see if the application is performing those checks:

1. Go to the Sign up page
2. Create two user accounts - Tom and Jerry
3. Go to Admin > Manage Users
4. Edit user Tom's rewards points to 3000
5. Navigate to Admin > Ticket to Mars



The page is working. App says Tom is eligible and Jerry is not.

We need to find a way to get two tickets to Mars. How can we do that? What if we transfer points from Tom's account to Jerry's account immediately before the app checks Jerry's balance? Let us try that

It's time to slow down TimeGap Theory:

1. On your browser, navigate to TimeGap Theory > Settings
2. Change the Mars wait to 5 seconds
3. Click on the Save button

Now, TimeGap Theory will wait 5 seconds before every database write operation.

Preparation phase

1. Open transfer rewards page
2. Click on the first $10 from Tom to Jerry button
3. Change the transfer amount to 2000

Alright, the preparation is done. Here comes the exploitation phase.

Exploitation phase

1. Open another browser or private/incognito window
2. On the new window, navigate to TimeGap Theory > Webapp > Admin > Ticket to Mars
3. Immediately go to the first bowser window and click on the Transfer button

Let us see that worked or not

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Post-exploitation phase

1. Let us wait for both the browsers to complete the request
2. You can see that both Tom and Jerry got tickets to Mars
3. If you check the balance of Tom, you will see that their balance is less than 2000
4. If you check your scores, you will see that you have got 100 points for completing the Mars challenge.
5. Don't forget to change the Main Wait to 0 on settings page.

We are skipping the automation part for this chapter. In the real world, attackers would use the same automation technique as mentioned in the transfer-rewards page. Then, they will schedule their automation program to run at a specific time they have chosen. If the attacker knows from their past experience that the Ticket to Mars program usually starts running at 12am on January 1st, they will schedule their attack script to trigger at the exact time.

What would be the business impact of such an attack? Depending on how the app is designed, there are several possibilities:

1. Users may keep on circling their points/money to get the benefits
2. Business will end-up spending too much on benefits compared to what they were anticipating

Let us review what we did:

1. The Ticket to Mars program gives some benefits to users if they have reward points more than 2000
2. You checked this functionality first
3. You slowed down the system and bypassed the business logic

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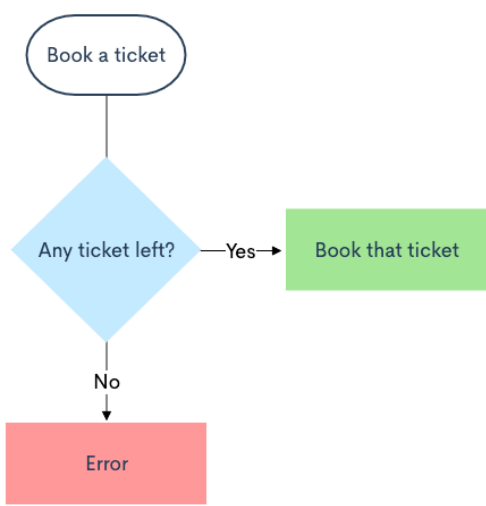
CHAPTER 8

Challenge 5 – Tickets

Get tickets to the Show.
Enjoy the Show.

Enjoy going to the movies? This page is for booking the show. Unfortunately, there is only one ticket left. All the other tickets were sold offline. Whoever is able to complete the transaction first will get the ticket.



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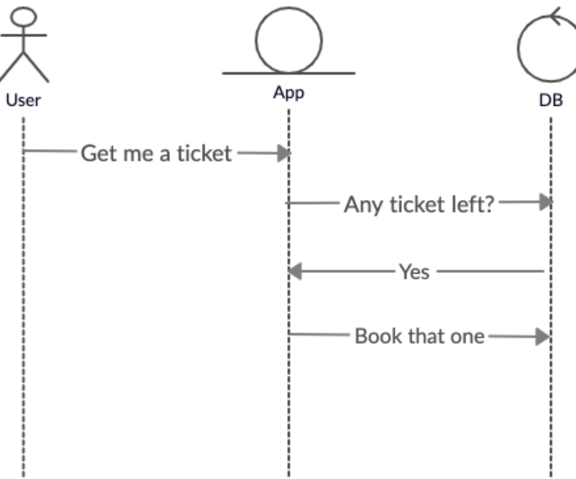
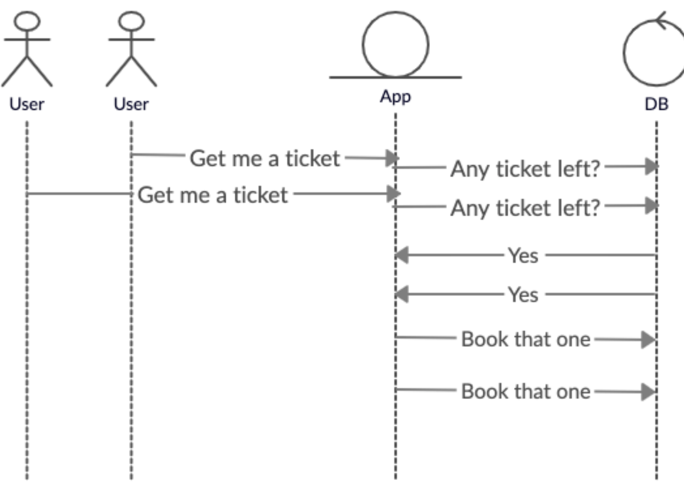
Let us visualize the happy path with the help of a sequence diagram:



That is just the happy path for one user purchasing a ticket. Let us reimagine the same scenario but with two users acting at the same time.



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There is only one condition to be met for a user to purchase the ticket - there should be at least one ticket available in the system.

Let us see if the application is performing those checks:

1. Go to the login page
2. Login as any user
3. Navigate to the buy tickets page
4. Click on Buy One Ticket button
5. Observe the message You have 1 ticket(s) message on top of the page
6. Click on Buy One Ticket button again
7. See that nothing happens
8. Logout and login as another user
9. Navigate to the buy tickets page
10. Click on Buy One Ticket button
11. See that user is not able to buy tickets since there are no more tickets left

We need to find a way to purchase two tickets. How can we do that? What if we click on the buy ticket button multiple times very fast? That won't help cause the page needs to be loaded after each click.

It's time to slow down TimeGap Theory:

1. On your browser, navigate to the Settings page
2. Change the time delay to 5 seconds
3. Click on the Save button

Now, TimeGap Theory will wait 5 seconds before every database write operation.

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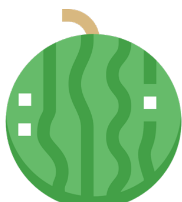
Preparation phase

1. Navigate to the Admin page
2. Click on the create default users button
3. Open two browsers side by side (Use private/incognito window if you do not have two browsers)
4. Navigate to the login page on both the browsers
5. On the first browser:
    a. Click on the first user button on top
    b. This will fill the user data for user Tom
    c. Submit the form to log in as Tom
6. On the second browser:
    a. Click on the second user button on top
    b. This will fill the user data for user Jerry
    c. Submit the form to log in as Jerry



Alright, the preparation is done. Here comes the exploitation phase.

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Exploitation phase

1. On both the browsers:
    a. Navigate to the buy tickets page
    b. Click on the Buy One Ticket button

Let us see how that turns out.

Post-exploitation phase

1. Let us wait for both the browsers to complete the request
2. You can see that both the users have one ticket on their account
3. If you check your scores, you will see that you have got 100 points for completing the buy tickets challenge.
4. Don't forget to change the delay to 0 on the settings page.

Automation

As always, we need a way to automate this.

Pro-tip - you can skip this in real life if the webmaster is your friend and is ready to slow down the server for you.

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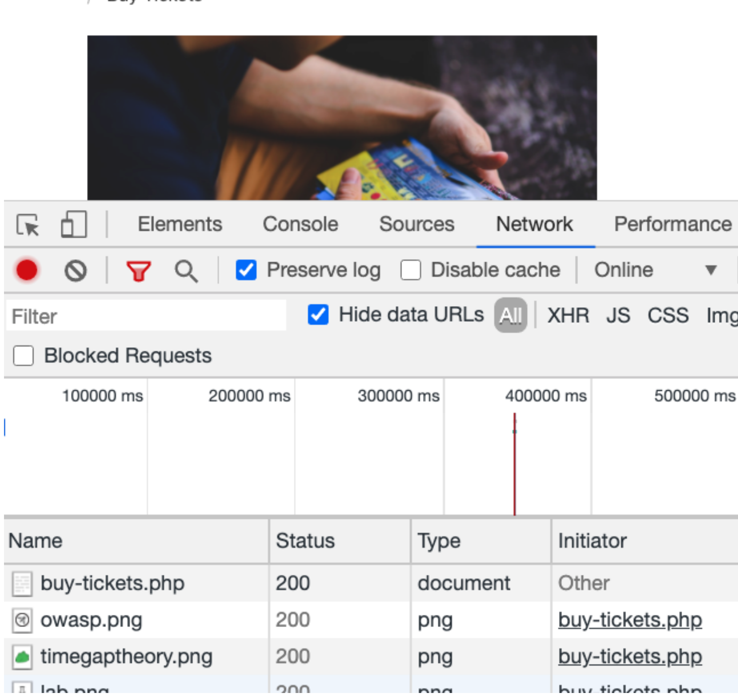
First, we need a valid fetch request:

1. Open your browser (Chrome or Firefox)
2. Navigate to TimeGap Theory > Webapp > Login
3. Click on the first user button. This will load the user data for Tom
4. Click on the Sign in button
5. Navigate to the buy tickets page
6. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
7. Click on the Buy one ticket button
8. On the browser dev tools, click on the Network tab
9. Right click on the buy-ticket.php request
10. Click on Copy > Copy as fetch

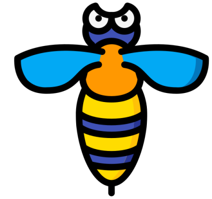


Paste that on the Console tab of the browser dev tools. You will get something like the following:

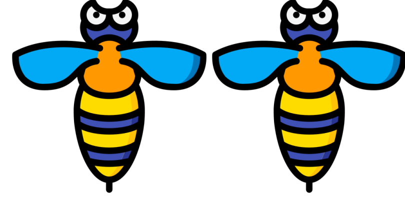
```
fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/buy-tickets.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": null,
  "method": "POST"
});
```

Based on how playful your browser is, you may see a slightly long fetch request. Feel free to trim it down to the bare minimum version shown above.

Now we have a request.



And we need two requests.



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It can be done by copy-pasting the fetch request without pressing the Enter key. However, it’s a good practice to separate each request with a comma. Let us do that

Elements Console Sources Network Performance Memory Application Security

top ▼ Filter Default levels ▼

```
fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/buy-tickets.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": null,
  "method": "POST"
}),fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/buy-tickets.php", {
  "headers": {
    "content-type": "application/x-www-form-urlencoded"
  },
  "body": null,
  "method": "POST"
});
```

Before running this new command, we need to clear the slate. It involves three simple steps:

1. Ensure that there is no delay
    a. Go to TimeGap Theory > Settings
    b. Ensure that the delay is set to 0
2. Reset database and create users
    a. Go to TimeGap Theory > Admin
    b. Click on reset database button
    c. Go back to TimeGap Theory > Admin
    d. Click on create default users button
3. Clear the current score
    a. Go to TimeGap Theory > Score
    b. Click on the Clear button

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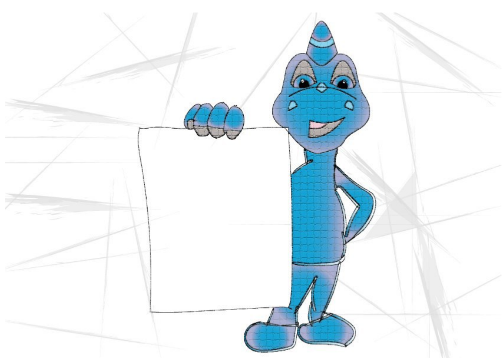

Alright, our slate is clear. Let us execute the attack now:

1. Navigate to the Login page
2. Click on the first user button on top. This will fill the user data for user Tom
3. Click on the Sign In button
4. Enter the combined fetch request on the Console tab of browser dev tools
5. Press the Enter key
6. Refresh the page
7. You will see that our attack attempt is unsuccessful.

What happened?

Two things went wrong:

1. The Buy Tickets page of TimeGap Theory is authenticated. We need to supply the cookie as well in order for this request to be successful
2. Since an authenticated session is involved, webapp is treating the executing requests one by one when it is from the same session

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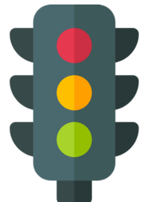
We need to solve both these problems for the automation to be successful.

Problem 1 - Cookie

Fetch request does not support sending cookies. We need an alternate solution. cURL supports sending cookies. We can use that.

Problem 2 - Only one request per session



This can be solved by creating two sessions for the same user. How can we do that?

1. We will sign into Tom's account on the first browser.
2. We will sign into Jerry's account on the second browser.

This way we will get two separate active sessions.

Now, we need valid cURL requests with session tokens in it.

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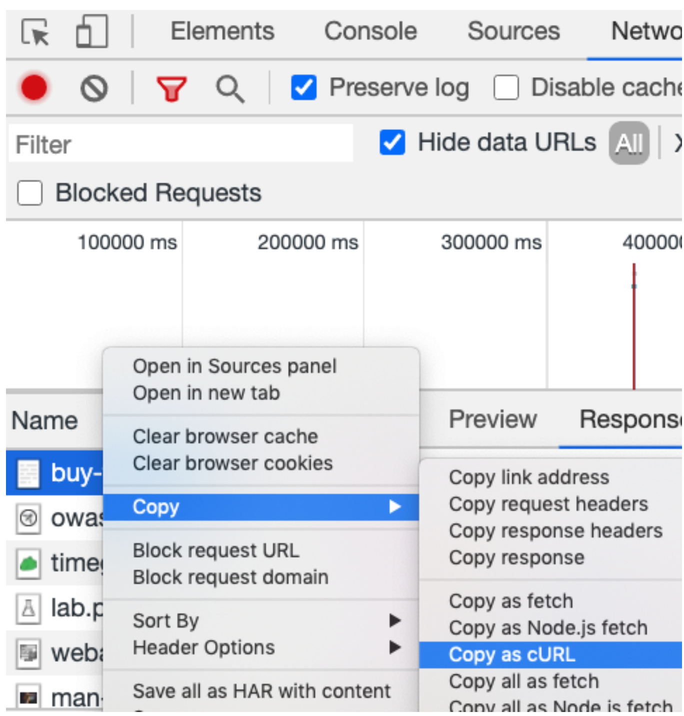
Let us obtain the first one:

1. Open your browser (Chrome or Firefox)
2. Navigate to TimeGap Theory > Webapp > Login
3. Click on the first user button. This will load the user data for Tom
4. Click on the Sign in button
5. Navigate to the Buy Tickets page
6. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
7. Click on the Buy One Ticket button.
8. On the browser dev tools, click on the Network tab
9. Right-click on the buy-tickets.php request.
10. Click on Copy > Copy as cURL



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For getting the second one:

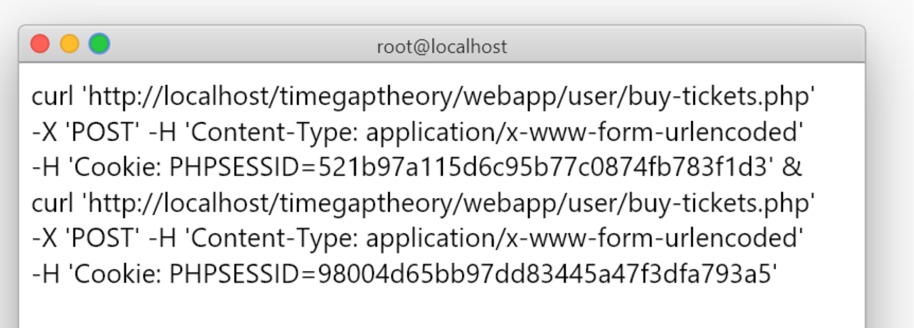
1. Open another browser (Chrome or Firefox)
2. Navigate to TimeGap Theory > Webapp > Login
3. Click on the second user button. This will load the user data for Jerry
4. Click on the Sign in button
5. Navigate to the Buy Tickets page
6. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
7. Click on the Buy One Ticket button
8. On the browser dev tools, click on the Network tab
9. Right click on the buy-tickets.php request.
10. Click on Copy > Copy as cURL

Now that we have both the requests. Let us run them in parallel. Before doing that, we need to clear all the previous purchases of tickets. This can be done by reloading the create-users.php page located at TimeGapTheory > Webapp > Admin > Create Users.

Once you have reloaded the create-users.php page, follow the steps below:

1. Open your command prompt/Terminal window
2. If you are on Windows [5]
    a. Type start /b
    b. Put a space
3. Enter the first cURL request
4. Put a space
5. Enter the ampersand symbol (&) [6]
6. Put a space again
7. If you are on Windows
    a. Type start /b
    b. Put a space
8. Enter the second cURL request

9. If you are on Windows
    a. Remove the following parameter from both the requests "--compress". Some versions of cURL do not support this feature.
10. Now, press the Enter/Return key



Let us see if we are successful or not:
1. Go to the first browser window
2. Refresh the Buy Tickets page
3. Note the message on the top that says You have 1 ticket(s)
4. Go to the second browser window
5. Refresh the Buy Tickets page
6. Note the message on the top that says You have 1 ticket(s)
7. Check if you got points for completing the Buy Tickets challenge

What would be the business impact of such an attack? Depending on how the app is designed, there are several possibilities:
1. A legitimate user may show up for the show and realize that another user also got the same ticket
2. Business would end up having unhappy customers, giving compensations etc.

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Let us review what we did:

1. The buy tickets page checks the stock of the tickets before allowing the user to book it
2. You analyzed this behavior by trying to purchase two tickets
3. First, you slowed down the system and bypassed the business logic
4. Then you tried bypassing the business logic using fetch requests on browser dev tools and failed
5. You learned that fetch requests are not useful while trying to send cookies to the server
6. You moved onto cURL as it supports sending cookies and you were able to purchase one ticket each for two users.
7. Now you know how TOC/TOU security issues can affect buy tickets pages

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CHAPTER 9

Challenge 6 – Coupon

One-time use coupons.
Get extra rewards.

We all love coupons. Coupons help you get additional discounts or points. The only problem with them is that they can only be used once. Same is the scenario here. There is a one-time coupon which can only be used once by a customer.

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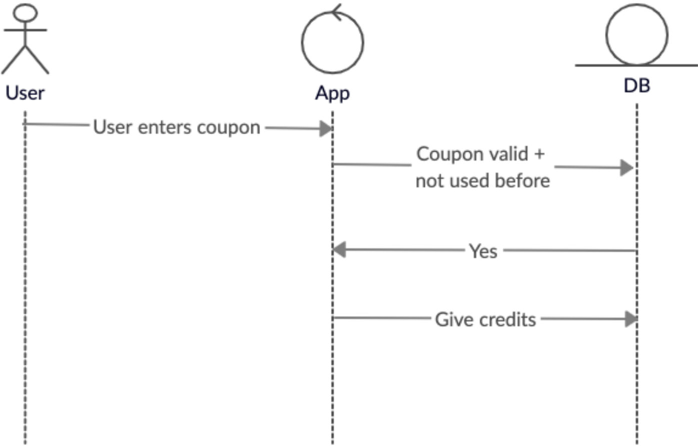
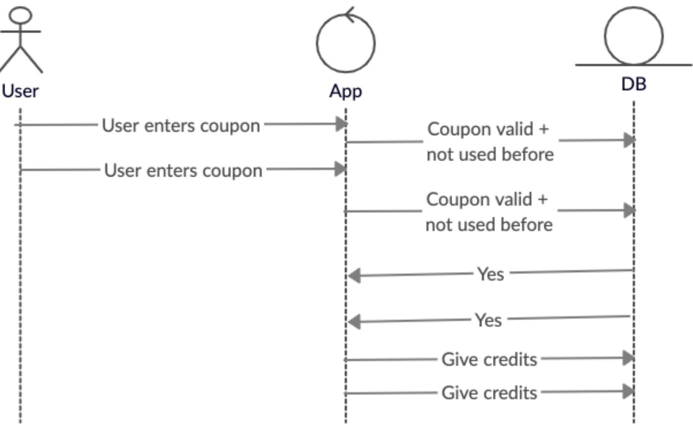
Let us visualize the happy path with the help of a sequence diagram:



That is just the happy path for one user entering a valid coupon once. Let us reimagine the same scenario but with the user sending two requests at the same time with a valid coupon.



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There are two conditions to be met for user to get credits from the coupon:

1. Coupon code should be valid
2. It should not have been used before

Let us see if the application is performing those checks:

1. Go to the Admin page
2. Click on create default users button
3. Navigate to the login page
4. Click on the first user button. This will fill in the user data for user Tom
5. Click on the Sign In button
6. Navigate to enter coupon page
7. Click on the Invalid token button on top. This will fill the coupon field with an invalid coupon code.
8. Click on the submit button
9. Note that the page is not accepting invalid coupons
10. Click on the valid token button on top. This will fill the coupon field with a valid coupon code.
11. Click on the submit button
12. You will see an increase in your reward points
13. You will also see you are our preferred customer message
14. Try repeating step number 10 and 11
15. You will see that the application is not accepting the same coupon anymore

We need to find a way to use the coupon code twice. How can we do that? What if we submit the valid coupon twice?

It's time to slow down TimeGap Theory:

1. On your browser, navigate to the settings page
2. Change the time delay to 5 seconds
3. Click on the Save button

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Now, TimeGap Theory will wait 5 seconds before every database write operation.

Preparation phase

1. Navigate to the Admin page
2. Click on the reset database button
3. Click on the create default users button
4. Open two browsers side by side (Use private/incognito window if you do not have two browsers)
5. On both the browsers:
    a. Navigate to the login page
    b. Click on the first user button on top. This will fill the user data for user Tom
    c. Submit the form to log in as Tom
    d. Navigate to the enter coupon page
    e. Note down the current reward points

Alright, the preparation is done. Here comes the exploitation phase.

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Exploitation phase

1. Click on the Submit button on the first browser
2. Go to the second browser as soon as you can
3. Click on the Submit button on the second browser

That's it. Let us see the result:

Post-exploitation phase

1. Let us wait for both the browsers to complete the request
2. Check the rewards points on Tom's account
3. You will see that you got more than 500 points with the help of same coupon
4. If you check your scores, you will see that you have got 100 points for solving the Coupon challenge
5. Don't forget to change the delay to 0 on the settings page.

What would be the business impact of such an attack? Depending on how the app is designed, there are several possibilities:

1. Users will use one-time tokens and coupons multiple times
2. Business can suffer from financial issues

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Let us review what we did:

1. The enter coupon page limits the number of times one-time coupons can be used
2. You analyzed this behavior by trying to use same coupon multiple times
3. You slowed down the system and bypassed the business logic
4. Now you know how TOC/TOU security issues can affect one-time-use coupons and tokens

We are skipping the automation part for this chapter. The steps would be the same as the Buy Tickets challenge but with a slight change. Since you are trying to apply the coupon to one user account multiple times, you need to get two active sessions for the same user. This can be done by:

1. Navigating the login page on the first browser and logging in as Tom
2. Navigating the login page on the second browser and again logging in as Tom

Without creating two sessions, automation attempts would fail as the application will process requests originating from the same session one by one.

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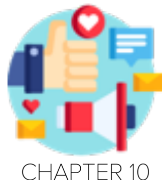

CHAPTER 10

Challenge 7 – Ratings

Rate them high.
Rate them good.

Ratings systems are one of the main features of social web apps these days. Sometimes it is a simple like/love button or it can be a full-fledged five-star rating system. A user is supposed to rate an object only once.

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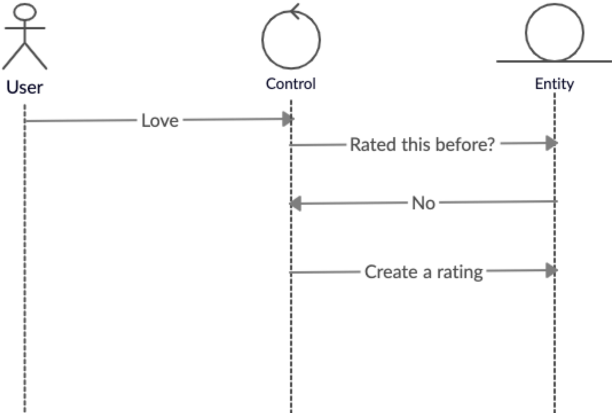
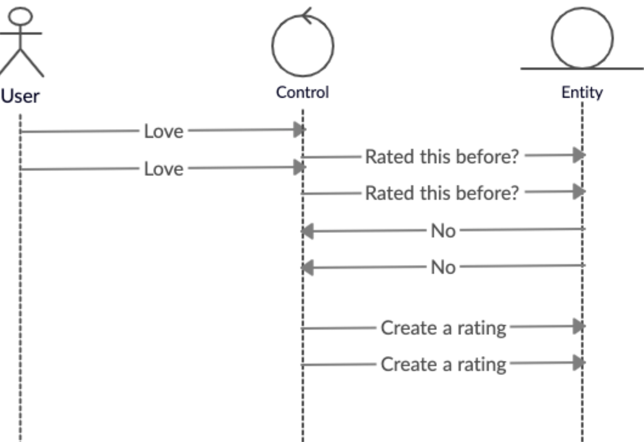
Let us visualize the happy path with the help of a sequence diagram:



That is just the happy path for one user rating the post. Let us reimagine the same scenario but with the same user acting at the same time from two browsers.



There is only one condition to be met for a user to rate a show - they shouldn't have rated the show before. If they have already rated the show, the app will remove the existing rating from the database.

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Let us see if the application is performing those checks:

1. Go to the Admin page
2. Click on reset database button
3. Go back to the Admin page
4. Click on Create default users button
5. Navigate to the login page
6. Click on the first user button. This will load the user data for user Tom
7. Click on the Sign in button
8. Navigate to rate the program page
9. Click on the Love button
10. Note the message on the top that says You have 1 rating(s)
11. Click on the Love button again
12. Note the message on the top that says You have 0 rating(s)

We need to find a way to rate the program twice. How can we do that? What if we submit two rating requests in parallel?

Let us slow down TimeGap Theory:

1. On your browser, navigate to the Settings page
2. Change the time delay to 5 seconds
3. Click on the Save button

Now, TimeGap Theory will wait 5 seconds before every database write operation.

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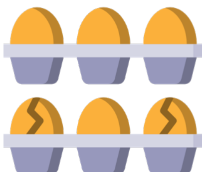
Preparation phase

1. Navigate to the Admin page
2. Click on the reset database button
3. Click on the create default users button
4. Open two browsers side by side (Use private/incognito window if you do not have two browsers)
5. On both the browsers:
    a. Navigate to the login page
    b. Click on the first user button on top. This will fill the user data for user Tom
    c. Submit the form to log in as Tom
    d. Navigate to the rate the program page



Alright, the preparation is done. Here comes the exploitation phase.

Exploitation phase

1. Click on the Love button on the first browser
2. Go to the second browser as soon as you can
3. Click on the Love button on the second browser

That's it. Let us see the result:

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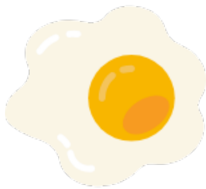
Post-exploitation phase

1. Let us wait for both the browsers to complete the request
2. Note the message on the top that says You have 2 rating(s)
3. If you check your scores, you will see that you have got 100 points for solving the rate the program challenge
4. Don't forget to change the delay to 0 on the Settings page.



Automation time

As always, we need a way to automate this.

Pro-tip - you can skip this in real life if the webmaster is your friend and is ready to slow down the server for you.

First, we need a valid fetch request:

1. Open your browser (Chrome or Firefox)
2. Navigate to TimeGap Theory > Webapp > Login
3. Click on the first user button. This will load the user data for Tom
4. Click on the Sign in button
5. Navigate to the rate the program page
6. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
7. Click on the Love button
8. On the browser dev tools, click on the Network tab
9. Right click on the rate-the-program.php request
10. Click on Copy > Copy as fetch

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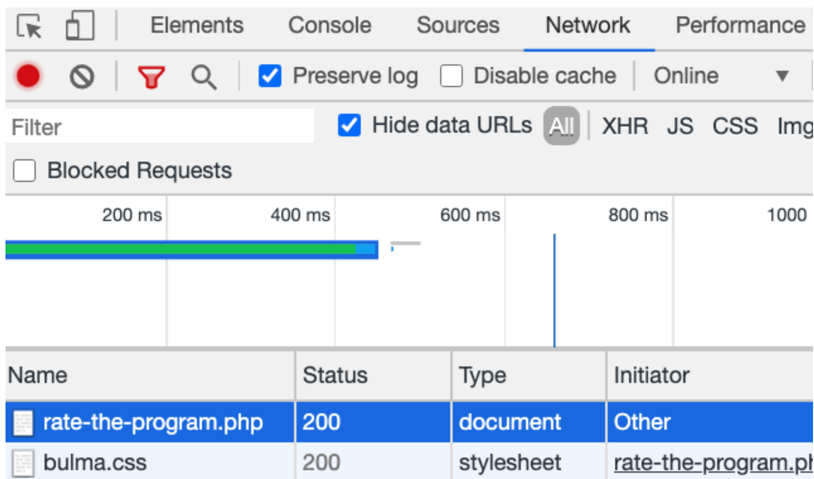


Paste that on the Console tab of the browser dev tools. You will get something like the following:

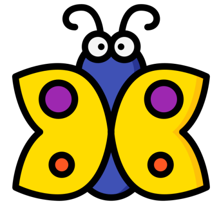
Elements | Console | Sources | Network | Performance | Memory | Application | Security

top ▾ | Filter | Default levels ▾

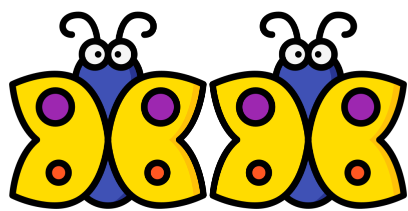
```
> fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/rate-the-program.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "token=3fa845e653632dc58c3a8432f937680931879e8031c4029699b7efaa9801db26&submit=Love",
    "method": "POST"
  });
```

Based on how playful your browser is, you may see a slightly long fetch request. Feel free to trim it down to the bare minimum version shown above.

Now we have a request.



And we need two requests.



It can be done by copy-pasting the fetch request without pressing the Enter key. However, it is a good practice to separate each request with a comma. Let us do that

Elements Console Sources Network Performance Memory Application Security

top Filter Default levels

```
> fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/rate-the-program.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "token=3fa845e653632dc58c3a8432f937680931879e8031c4029699b7efaa9801db26&submit=Love",
    "method": "POST"
  }),fetch("https://timegaptheory.herokuapp.com/timegaptheory/webapp/user/rate-the-program.php", {
    "headers": {
      "content-type": "application/x-www-form-urlencoded"
    },
    "body": "token=3fa845e653632dc58c3a8432f937680931879e8031c4029699b7efaa9801db26&submit=Love",
    "method": "POST"
  });
```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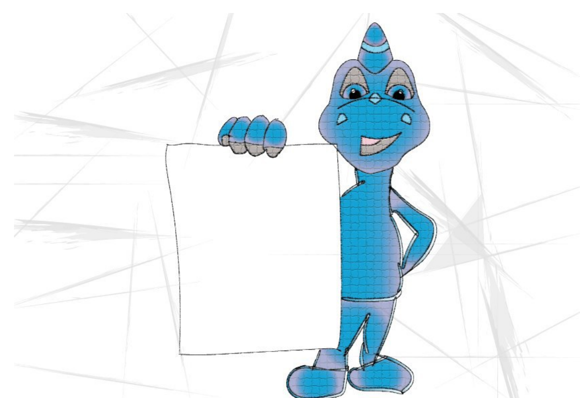
Before running this new command, we need to clear the slate. It involves three simple steps:

1. Ensure that there is no delay
    a. Go to TimeGap Theory > Settings
    b. Ensure that the delay is set to 0
2. Reset database and create users
    a. Go to TimeGap Theory > Admin
    b. Click on Reset database button
    c. Go back to TimeGap Theory > Admin
    d. Click on Create default users button
3. Clear the current score
    a. Go to TimeGap Theory > Score
    b. Click on the Clear button



Alright, our slate is clear. Let us execute the attack now:

1. Navigate to the Sign In page
2. Click on the first user button on top. This will fill the user data for user Tom
3. Click on the Sign In button
4. Enter the combined fetch request on the Console tab of browser dev tools

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5. Press the Enter key
6. Refresh the page
7. You will see that our attack attempt is unsuccessful.

What happened?

Three things went wrong in here:

1. TimeGap theory now has a CSRF prevention token in the request. This needs to be valid in order for the requests to be successful.
2. This page of TimeGap Theory is authenticated. We need to supply the cookie as well in order for this request to be successful
3. Since an authenticated session is involved, webapp is treating the executing requests one by one when it is from the same session

We need to solve all three problems.

Problem 1 - CSRF token

1. Open your browser and navigate to the Rate the program page
2. Open browser dev tools
3. Open the Network tab
4. Click on the Love button several times
5. On the dev tools, click on each request to rate-the-program page
6. See if we can find the nature of the anti-CSRF token
7. Note that the anti-CSRF token is same across all the requests

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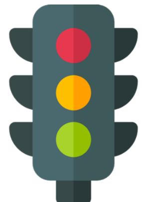
Problem 2 – Cookie

Fetch request does not support sending cookies. We need an alternate solution. cURL supports sending cookies. We will use that.

Problem 3 - Only one request per session



This can be solved by creating two sessions for the same user. How can we do that? We will just sign into the same account from two different browsers. Each session will be having their own anti-CSRF token as well.

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First, we need two valid cURL requests.

Let us obtain the first one:

11. Open your browser (Chrome or Firefox)
12. Navigate to TimeGap Theory > Webapp > Login
13. Click on the first user button. This will load the user data for Tom
14. Click on the Sign-in button
15. Navigate to the rate the program page
16. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
17. Click on the Love button.
18. On the browser dev tools, click on the Network tab
19. Right-click on the enter-coupon.php request.
20. Click on Copy > Copy as cURL

For getting the second one:

11. Open another browser (Chrome or Firefox)
12. Navigate to TimeGap Theory > Webapp > Login
13. Click on the first user button. This will load the user data for Tom
14. Click on the Sign-in button
15. Navigate to the rate the program page
16. Open up dev tools by pressing F12 on the browser
    a. On Windows, you can use Ctrl + Shift + I
    b. On Mac, you can use Cmd + Shift + I
17. Click on the Love button.
18. On the browser dev tools, click on the Network tab
19. Right click on the enter-coupon.php request.
20. Click on Copy > Copy as cURL

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Now that we have both the requests. Let us run them in parallel:

1. Open your command prompt/Terminal window
2. If you are on Windows
    a. Type start /b
    b. Put a space
3. Enter the first cURL request
4. Put a space
5. Enter the ampersand symbol (&)
6. Put a space again
7. If you are on Windows
    a. Type start /b
    b. Put a space
8. Enter the second cURL request
9. If you are on Windows
    a. Remove the following parameter from both the requests --compress. Some versions of cURL do not support this feature.
10. Now, press the Enter/Return key.

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Let us see if we are successful or not:

1. Go back to any of your browser window
2. Refresh the rate the program page
3. Note the message on the top that says You have 2 rating(s)
4. Check if you got points for completing the rate the program challenge

What would be the business impact of such an attack? Depending on how the app is designed, there are several possibilities:

1. Users will be able to bombard the system with infinite number of fake ratings/reviews
2. If this is an online election system, voters would be able to make multiple votes

Let us review what we did:

1. The rate the program feature limits the number of times one can rate the program
2. You analyzed this behavior by trying to rate the program multiple times
3. First, you slowed down the system and bypassed the business logic
4. Then you tried bypassing the business logic by using browser dev tools
5. You learned the difficulties involved in exploiting TOCTOU vulnerabilities when there is an authenticated session
6. Now you know how TOC/TOU security issues in the real world

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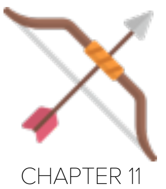

CHAPTER 11

More Tools

Start with whatever tools you may have.
Better tools will be found as you go.

Using a tool can help you find and exploit TOCTOU issues. There are a couple of such tools available in the open-source world:

Name	Notes
Browser Dev Tools	● Very easy to find ● Comes with major browsers ● Does not support sending cookies
cURL	● Easy to get ● Works on almost all the platforms ● Supports sending cookies ● https://curl.haxx.se/

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RaceTheWeb	• Amazing tool geared for exploiting TOCTOU issues • Easy to integrate in CI/CD pipeline • Works on almost all the platforms • https://github.com/aaronhnatiw/race-the-web
Requests Racer	• Needs Python 3 to run • https://github.com/nccgroup/requests-racer
PyRace	• Needs Python 2 to run • https://github.com/llamasoft/pyrace

We will solve the last challenge using RaceTheWeb. The executable files for RaceTheWeb can be obtained from https://github.com/aaronhnatiw/race-the-web/releases

Which version to download? It depends on the operating-system you are running

Operating System	**FIle to be downloaded**
Linux 32-bit	race-the-web_2.0.1_lin32.bin
Linux 64-bit	race-the-web_2.0.1_lin64.bin
macOS 32-bit	race-the-web_2.0.1_osx32.app.zip
macOS 64-bit	race-the-web_2.0.1_osx64.app.zip
Windows 32-bit	race-the-web_2.0.1_win32.exe
Windows 64-bit	race-the-web_2.0.1_win64.exe

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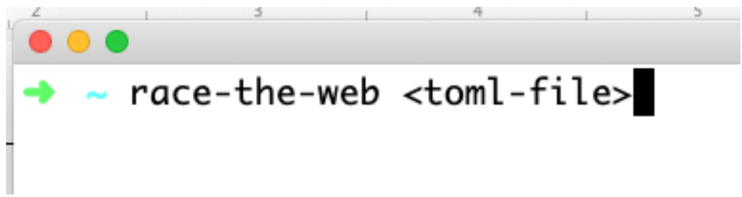
On Linux and macOS machines, you need to make the file executable.

Operating System	**Command to run on Terminal**
race-the-web_2.0.1_lin32.bin	chmod +x race-the-web_2.0.1_lin32.bin
race-the-web_2.0.1_lin64.bin	chmod +x race-the-web_2.0.1_lin64.bin
race-the-web_2.0.1_osx32.app.zip	Extract the zip file chmod +x race-the-web_2.0.1_osx32.app
race-the-web_2.0.1_osx64.app.zip	Extract the zip file chmod +x race-the-web_2.0.1_osx64.app

Running RacetheWeb is easy:

1. Open command prompt/Terminal
2. Navigate to the directory where you have extracted/downloaded the executable binary file
3. Run the following command:



race-the-web portion:

Depending on the operating-system you are using, the race-the-web portion needs to be changed.

Operating System	race-the-web portion
Linux 32-bit	./race-the-web_2.0.1_lin32.bin
Linux 64-bit	./race-the-web_2.0.1_lin64.bin
macOS 32-bit	./race-the-web_2.0.1_osx32.app
macOS 64-bit	./race-the-web_2.0.1_osx64.app
Windows 32-bit	race-the-web_2.0.1_win32.exe
Windows 64-bit	race-the-web_2.0.1_win64.exe

<toml-file> portion:

TOML stands for Tom's Obvious Minimal Language. The TOML file supplied should be having the request details so that race-the-web can run them.

Find TOML file for some of the TimeGap Theory challenges below:

Sign Up page

```
# Transfer Rewards

count = 10
verbose = false

[[requests]]
        method = "POST"
        url = "http://localhost/timegaptheory/webapp/sign-up.php"
        body =
"firstname=tom&password=tom&email=tom%40example.com&rewards=100"
```

In the above TOML file:

- Count defines how many requests RaceTheWeb tools would be sending in parallel
- Verbose defines the verbosity level of output that is displayed on the screen. The value of this can either be true or false
- Method defines the type of the request. This can be GET, POST, PUT, DELETE etc.
- URL is, well, the url at which request needs to be sent
- Body of the request. You can skip this part if there is no body that needs to be submitted

Sign In page

```
# Sign In Page

count = 1
verbose = true

[[requests]]
	method = "POST"
	url = "http://localhost/timegaptheory/webapp/login.php"
	body = "email=tom%40sechow.com&password=1234&submit=Submit"

[[requests]]
	method = "POST"
	url = "http://localhost/timegaptheory/webapp/login.php"
	body = 
"email=tom%40sechow.com&password=password&submit=Submit"

[[requests]]
	method = "POST"
	url = "http://localhost/timegaptheory/webapp/login.php"
	body = "email=tom%40sechow.com&password=tom&submit=Submit"
```

In the above TOML file:

- Count is 1. However, there are three requests in the file. As such, RaceTheWeb tool will send three parallel requests
- First two requests have wrong password in the request body

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Transfer rewards page

```
# Transfer Rewards

count = 10
verbose = false

[[requests]]
	method = "POST"
	url = "http://localhost/timegaptheory/webapp/user/transfer-rewards.php"
	body                                                                  =
"from=tom%40sechow.com&to=jerry%40sechow.com&amount=100&submit=Sub
mit"
```

Ratings page

```
# Ratings page

count = 1
verbose = false

[[requests]]
	method = "POST"
	url = "http://localhost/timegaptheory/webapp/user/rate-the-program.php"
	body                                                                  =
"token=ae13e0f1df6412dc4b9e2a9a3354320b6c1f3a65160bcffb552495759870af
a3"
	cookies = ["PHPSESSID=80c3ffddbfe4771dd408b3c53d4a7a44"]

[[requests]]
	method = "POST"
	url = "http://localhost/timegaptheory/webapp/user/rate-the-program.php"
	body                                                                  =
"token=bc5091b2f60da51d203a58b2af1c8bd99a443751adb206814d22df79e335
a3e5"
	cookies = ["PHPSESSID=fab00a2f7f46e33bb57deb4e08153e52"]
```

In the above TOML file, we are sending a cookie as well.

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Now you know:

1. Various open-source tools and techniques for finding and exploiting TOCTOU security issues
2. How to use RaceTheWeb tool for exploiting TOCTOU security issues
3. Writing TOML files for RaceTheWeb tool

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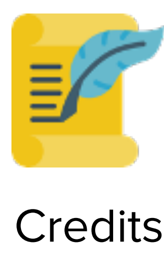

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You're a TOCTOU Champion now!

- You are equipped with tools and techniques to check if your application is vulnerable to TOCTOU
- You can forecast TOCTOU issues on applications by looking at the high-level design in threat-modeling sessions
- You are also in a position to demonstrate TOCTOU issues to your peers

Visit TimeGapTheory.com to learn more

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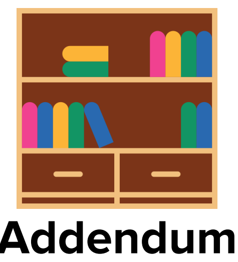

Addendum

1	OWASP Top 10	https://owasp.org/www-project-top-ten/
2	CWE's Top 25 Most Dangerous Software Errors	https://cwe.mitre.org/top25/archive/2019/2019_cwe_top25.html
3	Time-of-check to time-of-use	https://en.wikipedia.org/wiki/Time-of-check_to_time-of-use
4	Web app security testing with browsers	https://getmantra.com/web-app-security-testing-with-browsers/

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5	How to run multiple DOS commands in parallel?	https://stackoverflow.com/questions/11010834/how-to-run-multiple-dos-commands-in-parallel#comment93535098_11011212
6	How do I use cURL to perform multiple simultaneous requests?	https://stackoverflow.com/questions/9624967/how-do-i-use-curl-to-perform-multiple-simultaneous-requests#comment104563689_58228357 https://stackoverflow.com/questions/11010834/how-to-run-multiple-dos-commands-in-parallel#comment93535098_11011212
7	Racing the Web (Aaron Hnatiw)	https://www.youtube.com/watch?v=4T99v957I0o

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