Broken Authentication

White Hats: Team Members

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Description

The second web application security risk listed by the OWASP Foundation is broken authentication. Broken authentication occurs when an attacker either steals login data or forges session data, such as cookies, to gain access to a webapp. Once an attacker has broken into a user's account, they can view secure information such as credit card numbers, addresses, birthdates, social security numbers, etc… With this information, an attacker could then perform further nefarious actions such as social security fraud, identity theft, or simply disclosing highly sensitive information to others (owasp.org).

There are several vulnerabilities that need to be strengthened to protect against broken authentication. The degree that each web app strengthens itself is dependent on the information being stored. Session management is the most basic protection. Session management refers to the limitation of session duration from either login or the last action taken. It ensures that if a shared computer is utilized and the user neglects to logout, the next user has a reduced chance of being able to access the account (sitelock.com).

Another part of session management is ensuring that session hijacking is protected against. Session hijacking occurs when a hacker monitors your network activity while you are engaged in an active session. If they can parse the TCP packets, they have the potential to record your session information and reuse it, or to potentially interrupt and take control of your session. The most basic defense is ensuring that you never access sensitive data when using an exposed network. If you need to access it, then use a VPN to protect yourself.

The next major vulnerability that needs to be handled is protection against credential stuffing. Credential stuffing is where the attacker uses a script to brute force or automate an attack using a list of valid usernames and passwords. The most common defense against this is ensuring that your users choose passwords that are strong where strength of a password is primarily dictated by its length followed by the number/type of characters(password-depot.de).

Password recovery is the last vulnerability that many web applications should be strengthening. Security based questions used to be commonplace to recover login credentials, but they have been proven to be impossible to defend based on research from two security researchers. They state that "secret questions are neither secure nor reliable enough to be used as a standalone account recovery mechanism." They argue this based on an underlying flaw of secret questions;

they are either memorable or “somewhat secure”, but almost never both (security.googleblog.com).

The strongest form of protection against broken authentication is multifactor authentication, which is an authentication method that requires a user to present at least two pieces of evidence that they are the user they claim to be. The most common is a 2FA or two-factor authentication which typically combines: 1) something the user knows, 2) something the user has. A common example for this is an ATM transaction. The user must have and enter the card as well as know the PIN associated with the card to be granted access. While multifactor authentication provides the most security against broken authentication, it is also inconvenient to the user. Therefore, it has not yet become common practice unless the information stored has been deemed as excessively high-risk.

How to Attack our Site

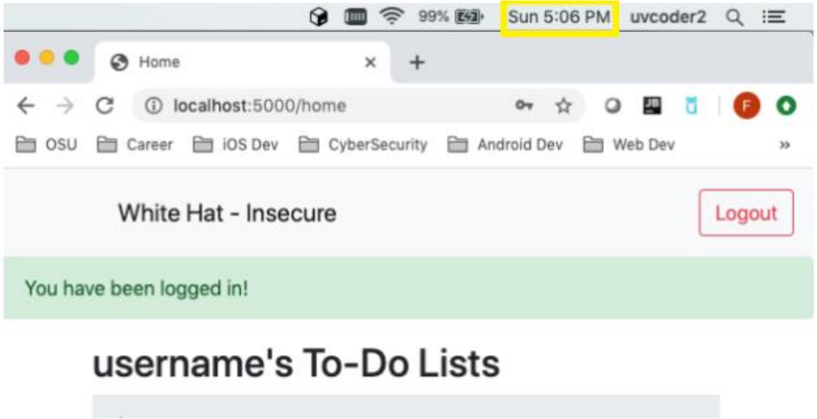
Session Management

Session ID Inactivity

Our insecure web application does not log a user out after a period of inactivity. A user may presume that because a window has been closed that their session has been logged out. Without explicitly logging out someone else may use the same computer and log into the previous users account without needing to log in.

To see this flaw login to your created account or a default account. Without logging out close the browser window and wait 5 minutes. Upon reopening the web page, you will be directed to the home page of the last logged in user.

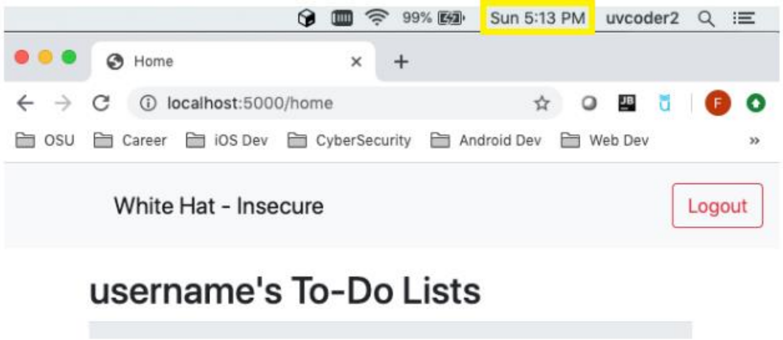
User’s initial log in: 5:06PM



You have been logged in!

username's To-Do Lists

After closing the browser, the same user remains logged in more than five minutes later: 5:13PM



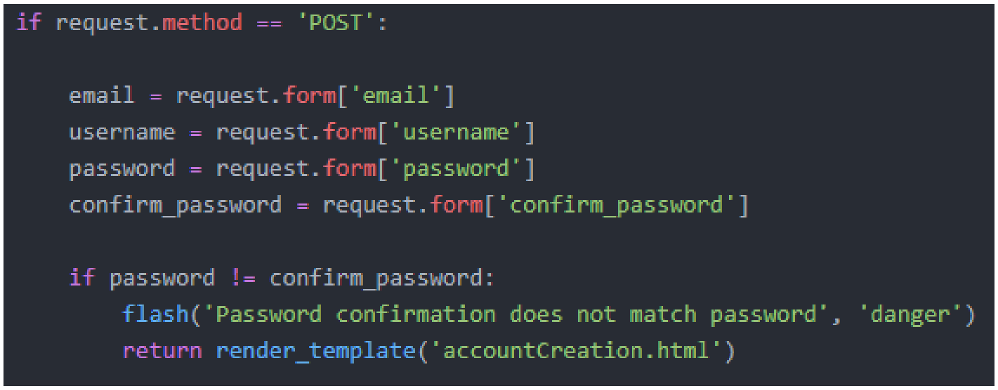
username's To-Do Lists

Passwords

Uncomplexed passwords

Our insecure web application does not enforce any rules for password complexity. Previous breaches of web sites have produced lists of commonly used passwords such as “password”, “qwerty”, and “abc123”. There are also lists of default and common usernames. An attacker can easily utilize automation methods to try thousands of these username and password combinations to try to guess their way into an account.

Here you can see our method of acquiring the password on the insecure site to register a new user. There is no requirement implemented for password complexity meaning a user could choose a single character as their password, which would be incredibly easy for a script to hack.



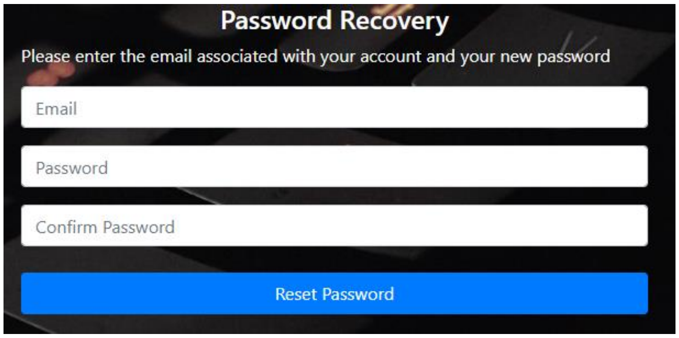
```
if request.method == 'POST':

    email = request.form['email']
    username = request.form['username']
    password = request.form['password']
    confirm_password = request.form['confirm_password']

    if password != confirm_password:
        flash('Password confirmation does not match password', 'danger')
        return render_template('accountCreation.html')
```

To visualize this flaw, from the login page click the link to “Sign Up”. On the “Sign Up” page create an account and use the simple password “123456”. Once back on the login page, sign into the newly created account with the weak password.

Recovery

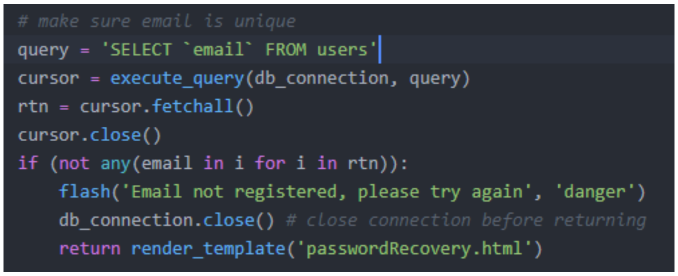
To recover your password on our insecure site, the only requirement is that you must know an email address that is in the database. Using SQL injection, an attacker could easily return a single row and change its user's password (read our how-to for SQL injection for more information). Since there are no additional securities to prevent an attacker from testing multiple different emails in rapid succession, credential stuffing would be incredibly effective here as well. For more on credential stuffing, continue below.

Only the email is required to reset the password:

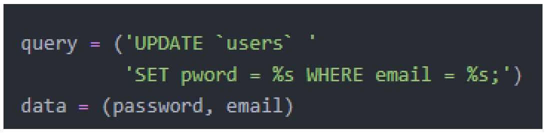


Password Recovery

Please enter the email associated with your account and your new password



```
# make sure email is unique
query = 'SELECT `email` FROM users'
cursor = execute_query(db_connection, query)
rtn = cursor.fetchall()
cursor.close()
if (not any(email in i for i in rtn)):
    flash('Email not registered, please try again', 'danger')
    db_connection.close() # close connection before returning
    return render_template('passwordRecovery.html')
```



```
query = ('UPDATE `users` '
         'SET pword = %s WHERE email = %s;')
data = (password, email)
```

Credential Stuffing

Brute Force

To perform brute force credential stuffing on our insecure site we can use a tool called Hatch. Hatch automates the process of attempting to log in to a website using a specified username and a list of possible passwords. An extended tutorial of how to use Hatch can be found here: https://null-byte.wonderhowto.com/how-to/brute-force-nearly-any-website-login-with-hatch-0192225/

To use Hatch:

1. Make sure you have Python 2 installed and then install: 'selenium' and 'requests'
    a. '$ pip2 install selenium'

    b. ‘$ pip2 install requests’

2. Download ChromeDriver and put the downloaded file into a directory named ‘**webdrivers**’ on your C drive
    a. http://chromedriver.chromium.org/downloads
3. Clone the Hatch repo
    a. https://github.com/nsgodshall/Hatch.git
4. Change to the directory where you cloned Hatch and run:
    a. ‘$ python2 main.py’
5. You will be prompted to enter the following:
    a. $ Enter a website: **https://osu-capstone-project-insecure.herokuapp.com/**
    b. $ Enter username selector*:* **body > div.container > div.row.mt-5 > div.col-8 > div > form > div:nth-child(1) > input**
    c. $ Enter password selector: **body > div.container > div.row.mt-5 > div.col-8 > div > form > div:nth-child(2) > input**
    d. $ Enter the login button selector: **body > div.container > div.row.mt-5 > div.col-8 > div > form > div:nth-child(3) > button**
    e. $ Enter the username to brute-force: **username**
        i. *‘username’ can be replaced with the username for which you would like to brute force, but for this example ‘username’ is a registered user with an insecure password that is included in ‘passlist.txt’ discussed in step 5f.*
    f. Enter a password list: **passlist.txt**
        i. *‘passlist.txt’ is a list of commonly used passwords that comes with the Hatch repo cloned in step 3. This file can be replaced by your own list of passwords or otherwise modified to suit your needs.*
6. Hatch will then attempt to log in to the username specified in step 5e sequentially with the list of passwords specified in step 5f until every password in the list is tried, the password is guessed, or you have been locked out of attempting to log in.
7. If the password for the specified username was included in the password list, once Hatch finishes running you will be logged into the site and the correct password will be displayed in the terminal.

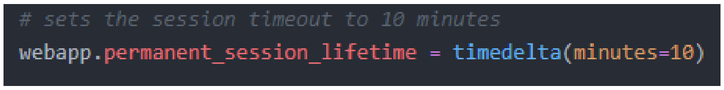
How to Defend our Site

Session Management

ID Timeout

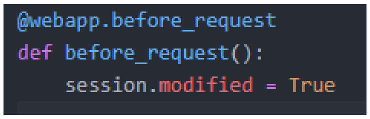
To defend against ID timeout, we implemented a permanent session lifetime for all logged in users of 10 minutes. Each time they take an action on the web application their session is modified with an updated time, allowing the session to be current for another 10 minutes.

Global variable for the webapp:



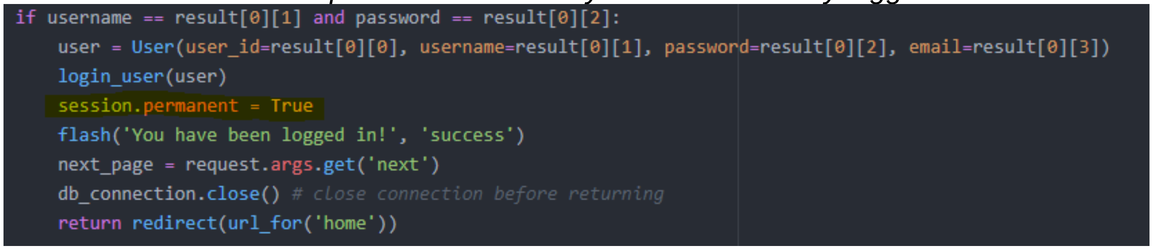
```
# sets the session timeout to 10 minutes
webapp.permanent_session_lifetime = timedelta(minutes=10)
```

Function that is called before each request is made updating their session.



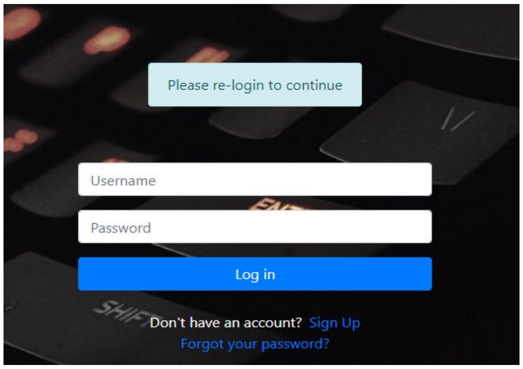
```
@webapp.before_request
def before_request():
    session.modified = True
```

Set the user's session to permanent after they have successfully logged in.



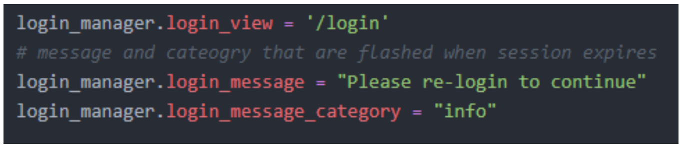
```
if username == result[0][1] and password == result[0][2]:
    user = User(user_id=result[0][0], username=result[0][1], password=result[0][2], email=result[0][3])
    login_user(user)
    session.permanent = True
    flash('You have been logged in!', 'success')
    next_page = request.args.get('next')
    db_connection.close() # close connection before returning
    return redirect(url_for('home'))
```

If a user’s session does timeout and they are required to re-login, they are returned to the login page using a flask_login module for LoginManager. It allows us to use the decorator, @login_required, before each function which requires the user be logged in. When they are returned to the login page, they are flashed a message giving them feedback that they must re-log in.



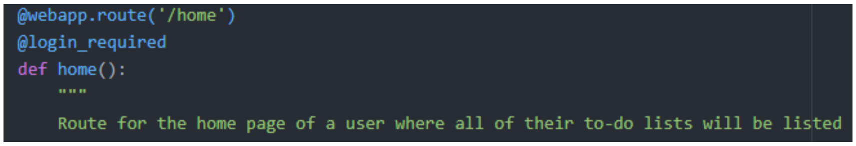
Please re-login to continue

Login_manager allows us to set the page we want rendered, the message to be flashed and the type of message (which sets the color of the flashed message).



```
login_manager.login_view = '/login'
# message and cateogry that are flashed when session expires
login_manager.login_message = "Please re-login to continue"
login_manager.login_message_category = "info"
```

Example: decorator before function that navigates to the home page

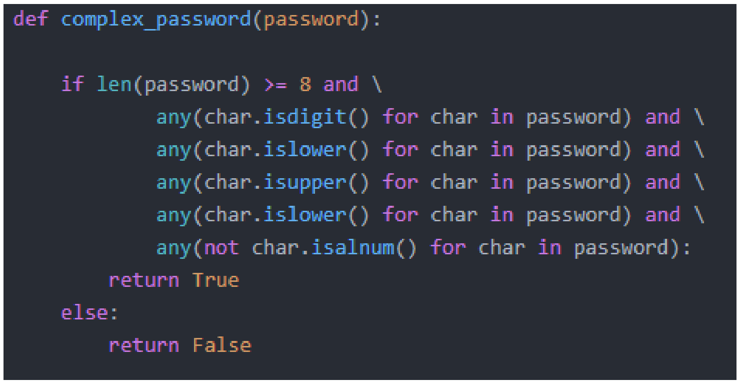


```
@webapp.route('/home')
@login_required
def home():
    """
    Route for the home page of a user where all of their to-do lists will be listed
```

Passwords

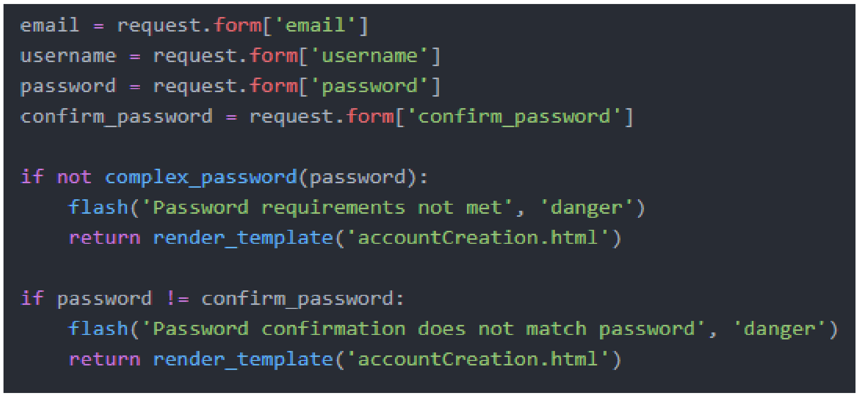
Strengthening

To defend against weak password credentials, we created a function to verify that a user’s password contains at least 8 characters with at least one lower case letter, uppercase letter, number, and special character. This combination leads to 95^8 or 6.6342043e+15 possible password combinations.



```
def complex_password(password):

    if len(password) >= 8 and \
            any(char.isdigit() for char in password) and \
            any(char.islower() for char in password) and \
            any(char.isupper() for char in password) and \
            any(char.islower() for char in password) and \
            any(not char.isalnum() for char in password):
        return True
    else:
        return False
```

This function is implemented in the registration page upon submission.



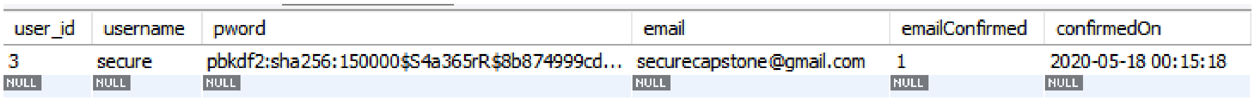
```
email = request.form['email']
username = request.form['username']
password = request.form['password']
confirm_password = request.form['confirm_password']

if not complex_password(password):
    flash('Password requirements not met', 'danger')
    return render_template('accountCreation.html')

if password != confirm_password:
    flash('Password confirmation does not match password', 'danger')
    return render_template('accountCreation.html')
```

Recovery

Part 1: User email confirmation

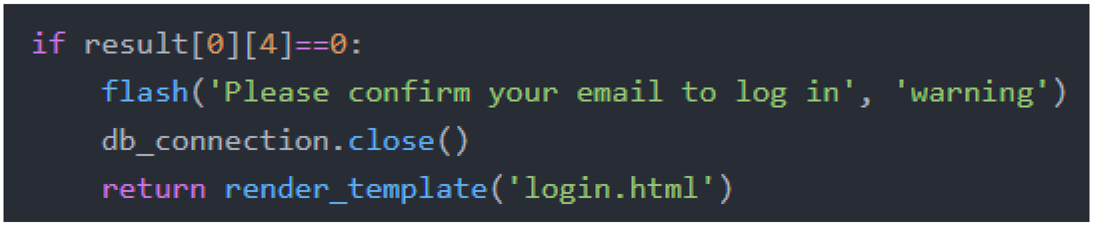
To strengthen password recovery, we first needed to implement email confirmation when users register. To do this, we would need to send a link to the email address they had entered when registering that would redirect them to our site and update their user row in our database with information stating they had confirmed their account.

We first needed to update our users table in the database to hold an emailConfirmed column.



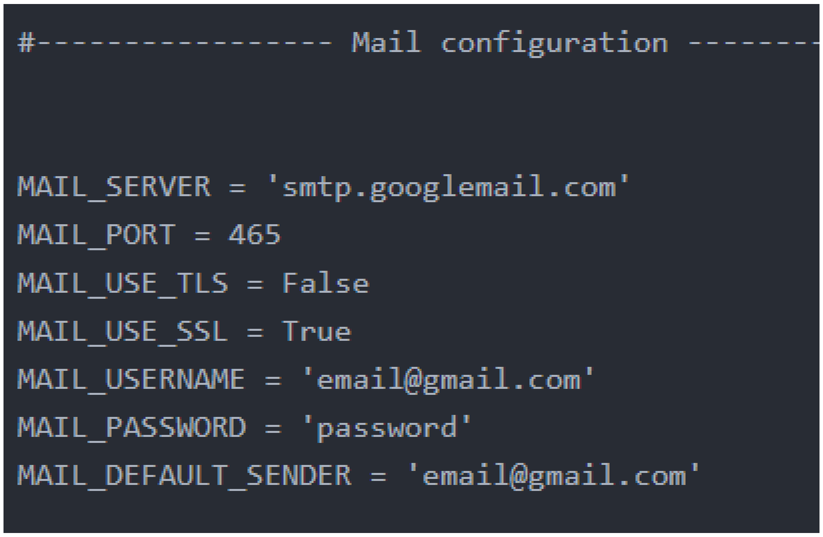
user_id	username	pword	email	emailConfirmed	confirmedOn
3	secure	pbkdf2:sha256:150000$S4a365rR$8b874999cd...	securecapstone@gmail.com	1	2020-05-18 00:15:18
NULL	NULL	NULL	NULL	NULL	NULL

We also wanted to make sure that users who attempted to login without confirming their account, would be redirected to the login page and informed that they would need to confirm their email before logging in. This function was added to the login view and checks the emailConfirmed column to see if the user has confirmed their email.



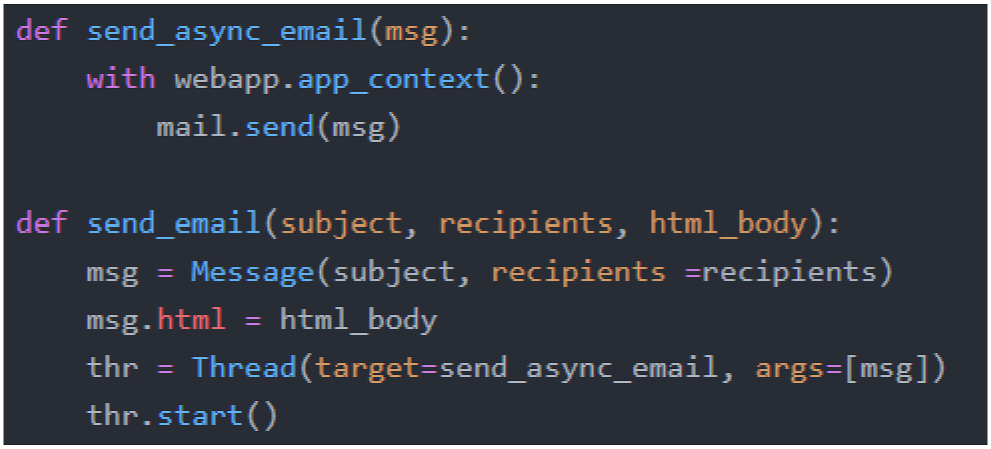
```
if result[0][4]==0:
    flash('Please confirm your email to log in', 'warning')
    db_connection.close()
    return render_template('login.html')
```

To send an email to each user, we decided to use a flask module, flask-mail. We just needed to add information to our configuration file that would inform flask-mail. (sample below)



```
#----------------- Mail configuration -------



MAIL_SERVER = 'smtp.googlemail.com'
MAIL_PORT = 465
MAIL_USE_TLS = False
MAIL_USE_SSL = True
MAIL_USERNAME = 'email@gmail.com'
MAIL_PASSWORD = 'password'
MAIL_DEFAULT_SENDER = 'email@gmail.com'
```

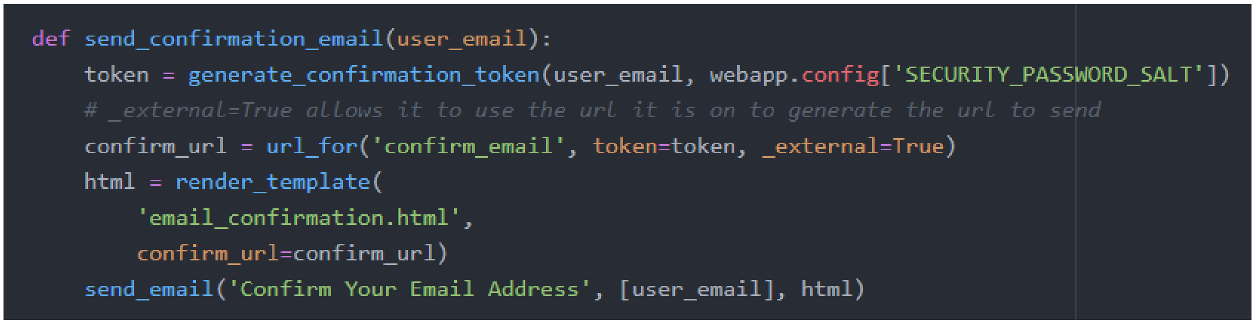
Then we set up our send_email function to take a subject, recipient, and html as arguments that we could call throughout our other views. We decided to send the emails asynchronously through the use of threads so that the user didn't have a delay between clicking the register button and being redirected to the next view while they waited for the email to be sent.



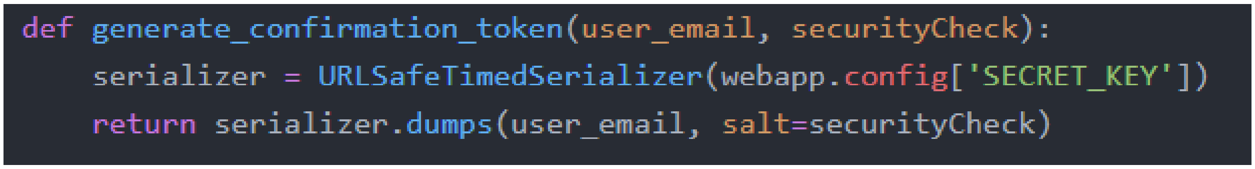
```python
def send_async_email(msg):
    with webapp.app_context():
        mail.send(msg)

def send_email(subject, recipients, html_body):
    msg = Message(subject, recipients =recipients)
    msg.html = html_body
    thr = Thread(target=send_async_email, args=[msg])
    thr.start()
```

We needed to generate a unique identifier each time that was specific to the user entry in the database. For this, we used the itsdangerous module. It allows us to generate a unique token based off a key and salted password. You can see the implementation of this below.

Create a token by calling generate_confirmation_token(), set the link url using a url_for() with all pieces required, set the html that will be viewed as an email, and finally send the email.

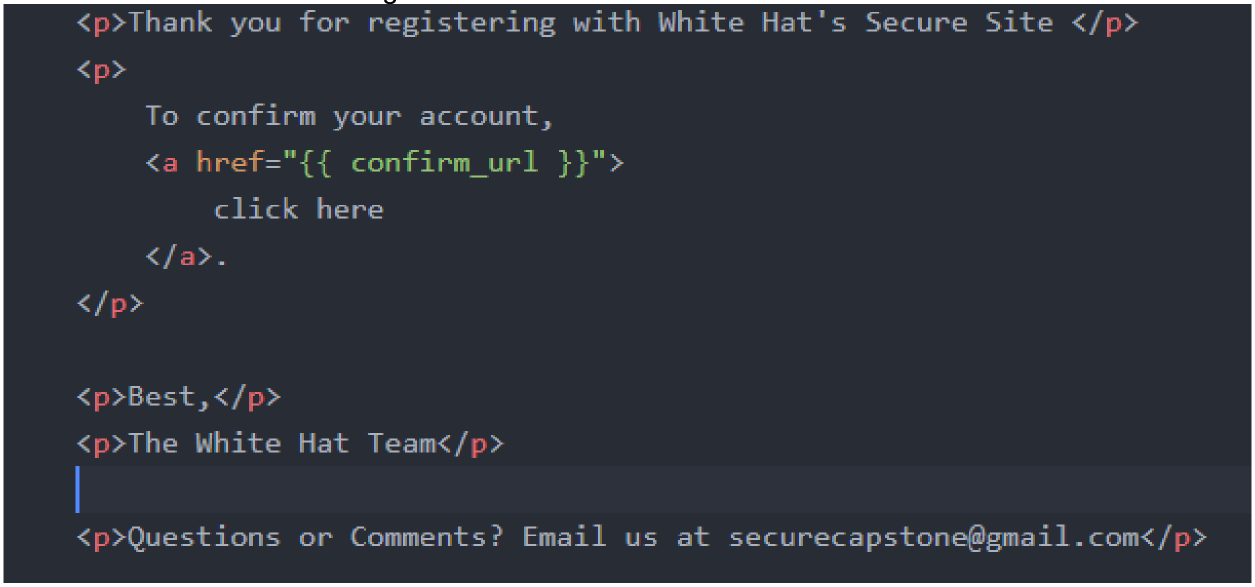


```python
def send_confirmation_email(user_email):
    token = generate_confirmation_token(user_email, webapp.config['SECURITY_PASSWORD_SALT'])
    # _external=True allows it to use the url it is on to generate the url to send
    confirm_url = url_for('confirm_email', token=token, _external=True)
    html = render_template(
        'email_confirmation.html',
        confirm_url=confirm_url)
    send_email('Confirm Your Email Address', [user_email], html)
```



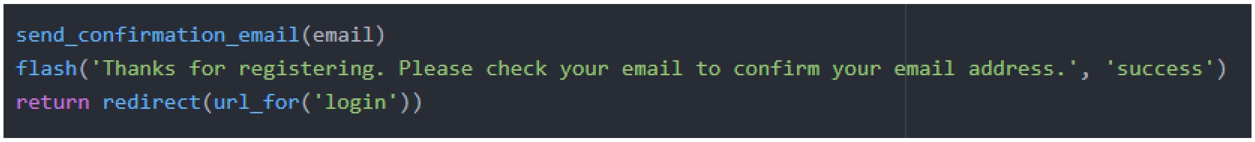
```python
def generate_confirmation_token(user_email, securityCheck):
    serializer = URLSafeTimedSerializer(webapp.config['SECRET_KEY'])
    return serializer.dumps(user_email, salt=securityCheck)
```

HTML sent as an email for registered user:



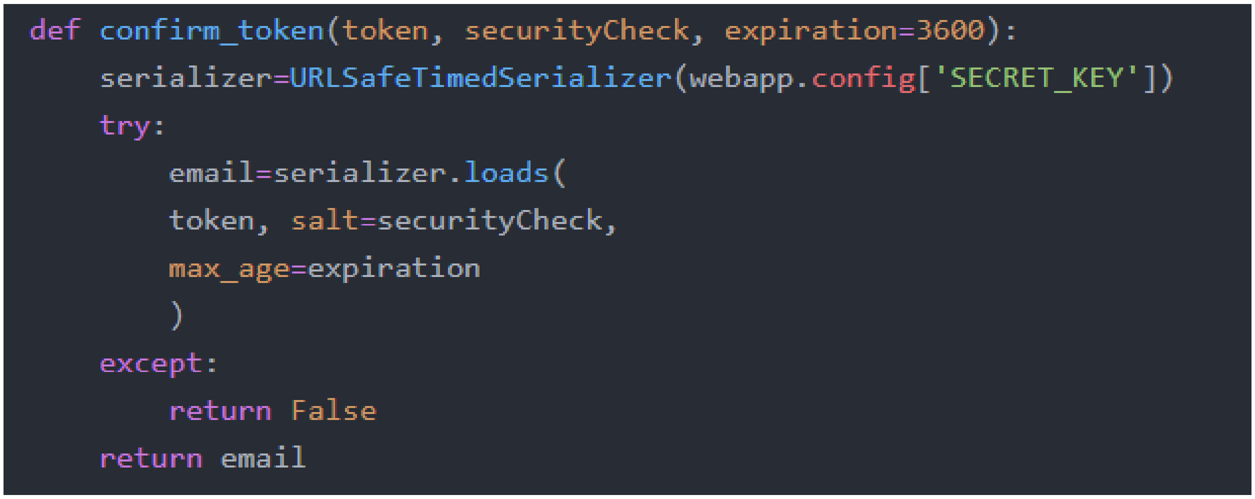
```html
    <p>Thank you for registering with White Hat's Secure Site </p>
    <p>
        To confirm your account,
        <a href="{{ confirm_url }}">
            click here
        </a>.
    </p>

    <p>Best,</p>
    <p>The White Hat Team</p>

    <p>Questions or Comments? Email us at securecapstone@gmail.com</p>
```

Now we just need to call send_confirmation_email() after any successful registration in the registration view.



```python
send_confirmation_email(email)
flash('Thanks for registering. Please check your email to confirm your email address.', 'success')
return redirect(url_for('login'))
```

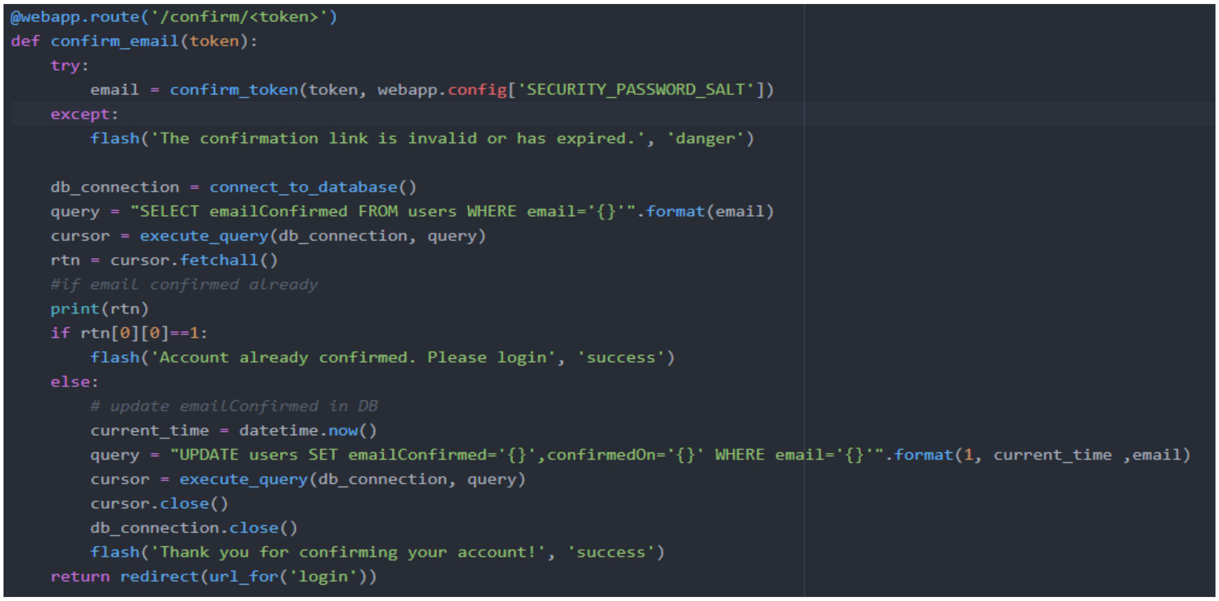
When they click the link passed in the email, they are redirected to a view that checks the authenticity of the token by calling confirm_token. This function checks that the url contains a token that has the appropriate salted password (securityCheck below) and a max_age less than 60 minutes. If those checks don't produce any errors, the email is returned as a result for the view to do further processing.



```python
def confirm_token(token, securityCheck, expiration=3600):
    serializer=URLSafeTimedSerializer(webapp.config['SECRET_KEY'])
    try:
        email=serializer.loads(
        token, salt=securityCheck,
        max_age=expiration
        )
    except:
        return False
    return email
```

The view that calls confirm_token is validating that the email it wants to extract from the token is valid to make sql queries with. Regardless of what happens in this view, the user is redirected to the login page of our site.

- If it fails this check, the user is redirected to the login page and flashed a message letting them know that the confirmation link is invalid or expired.
- If it passes, the view first checks that the user whose email this is associated with has not already confirmed their email.
    - If they have not, it updates the emailConfirmed property and redirects to the login screen and thanks them for confirming their account.



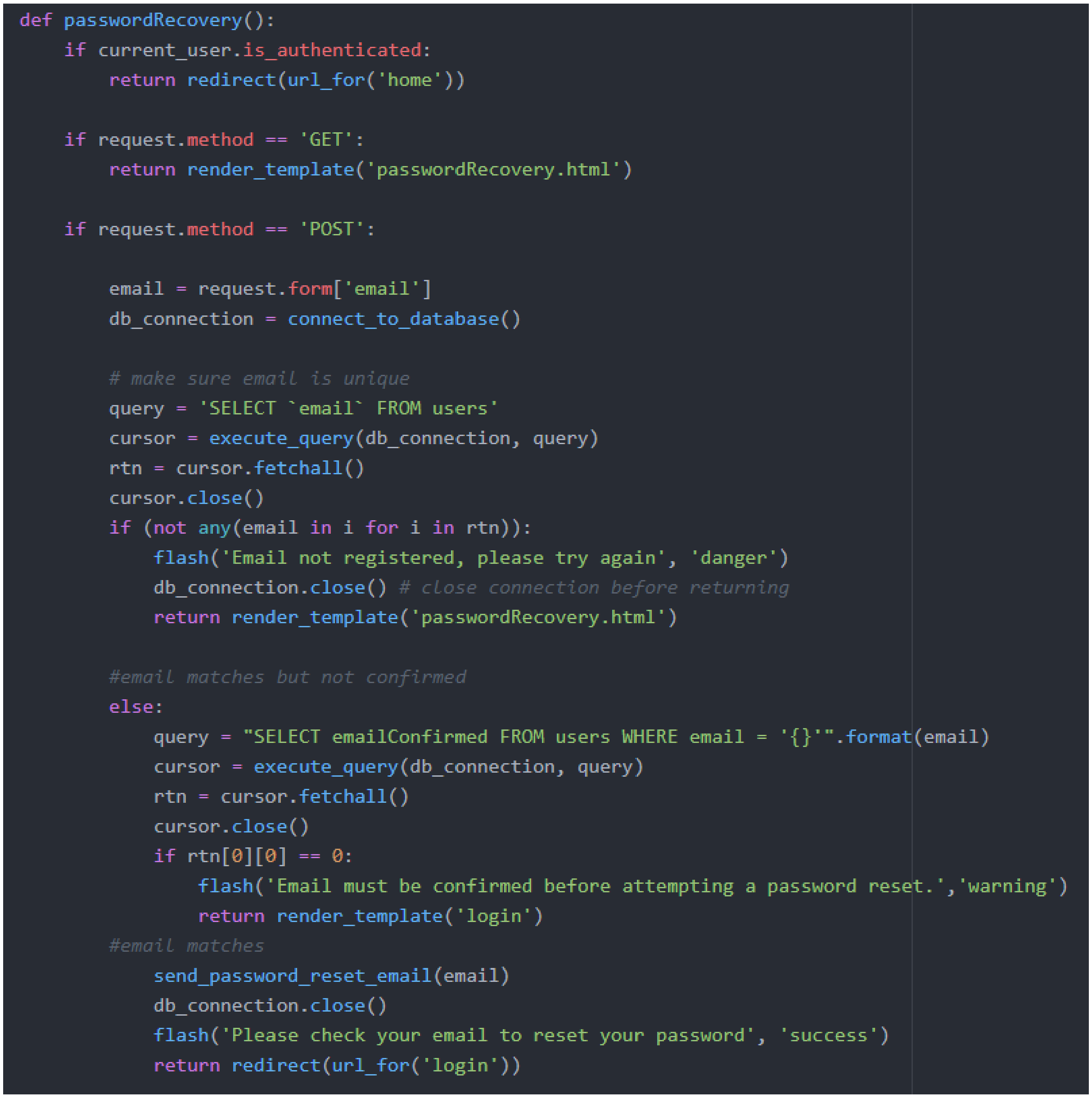
```python
@webapp.route('/confirm/<token>')
def confirm_email(token):
    try:
        email = confirm_token(token, webapp.config['SECURITY_PASSWORD_SALT'])
    except:
        flash('The confirmation link is invalid or has expired.', 'danger')

    db_connection = connect_to_database()
    query = "SELECT emailConfirmed FROM users WHERE email='{}'".format(email)
    cursor = execute_query(db_connection, query)
    rtn = cursor.fetchall()
    #if email confirmed already
    print(rtn)
    if rtn[0][0]==1:
        flash('Account already confirmed. Please login', 'success')
    else:
        # update emailConfirmed in DB
        current_time = datetime.now()
        query = "UPDATE users SET emailConfirmed='{}',confirmedOn='{}' WHERE email='{}'".format(1, current_time ,email)
        cursor = execute_query(db_connection, query)
        cursor.close()
        db_connection.close()
        flash('Thank you for confirming your account!', 'success')
    return redirect(url_for('login'))
```

So, we now have all the tools necessary to implement password recovery for a confirmed user account. We have essentially set up a two-factor authentication for the user. They need to know an email associated with an account in our database and they need to be able to login to that email account, two things they proved before successfully confirming their email with us.

Part 2: Forgotten password resetting

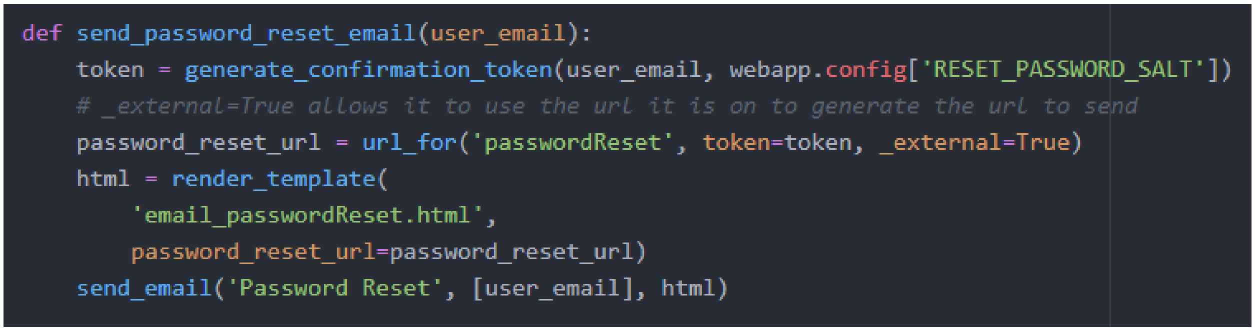
All the functions and views above are great templates to set up the next portion. We can reuse the send_email() and send_async_email() functions as well as the generate and confirm token function. So we just need to create an html page for the user to enter their email and corresponding view to handle it, a function much like send_confirmation_email() to send a password reset email, an html file representing the email to be sent, and a view that allows the user to reset the password.

Here is our password recovery view. It handles the html page that the user navigates to when they have forgotten their password. It only takes a single entry and compares a query's return with the user email, avoiding any potential SQL injection without using a procedure. If the email matches, it first checks to make sure it is confirmed. We do not want any users to be able to reset their passwords if they have not confirmed their email address. After this is done, it sends an email and redirects the user to the login page with a message to check their email.



```
def passwordRecovery():
    if current_user.is_authenticated:
        return redirect(url_for('home'))

    if request.method == 'GET':
        return render_template('passwordRecovery.html')

    if request.method == 'POST':

        email = request.form['email']
        db_connection = connect_to_database()

        # make sure email is unique
        query = 'SELECT `email` FROM users'
        cursor = execute_query(db_connection, query)
        rtn = cursor.fetchall()
        cursor.close()
        if (not any(email in i for i in rtn)):
            flash('Email not registered, please try again', 'danger')
            db_connection.close() # close connection before returning
            return render_template('passwordRecovery.html')

        #email matches but not confirmed
        else:
            query = "SELECT emailConfirmed FROM users WHERE email = '{}'".format(email)
            cursor = execute_query(db_connection, query)
            rtn = cursor.fetchall()
            cursor.close()
            if rtn[0][0] == 0:
                flash('Email must be confirmed before attempting a password reset.','warning')
                return render_template('login')
        #email matches
            send_password_reset_email(email)
            db_connection.close()
            flash('Please check your email to reset your password', 'success')
            return redirect(url_for('login'))
```

The function to send the password reset email is very similar to the send_confirmation_email function so I will not go into the same detail over it. However, it is important to note that we generated the token with a different password. This is an additional security measure so that if either token is compromised, only a small portion of the site is vulnerable.

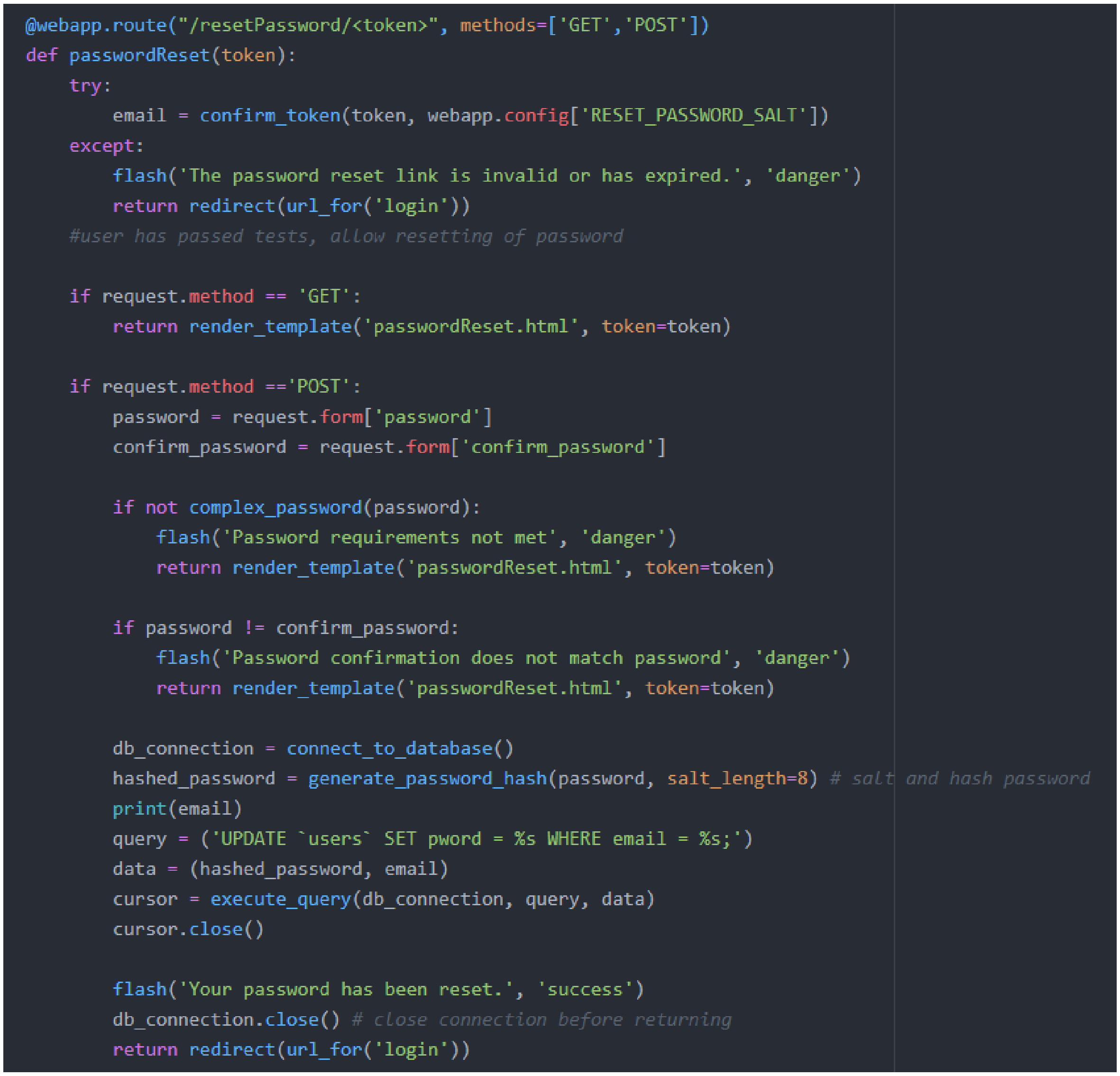


```python
def send_password_reset_email(user_email):
    token = generate_confirmation_token(user_email, webapp.config['RESET_PASSWORD_SALT'])
    # _external=True allows it to use the url it is on to generate the url to send
    password_reset_url = url_for('passwordReset', token=token, _external=True)
    html = render_template(
        'email_passwordReset.html',
        password_reset_url=password_reset_url)
    send_email('Password Reset', [user_email], html)
```

The view that needs to be made should confirm the token in the same way as our confirm_email view. If this is passed, then the user has access to this page and the next checks all result in being redirected back to this view:

- Check that the password entered meets complexity requirements
- Check that the passwords entered match

With both checks completed, we simply update the password in the database and redirect the user to the login screen with a message letting them know their password has been reset.



```python
@webapp.route("/resetPassword/<token>", methods=['GET','POST'])
def passwordReset(token):
    try:
        email = confirm_token(token, webapp.config['RESET_PASSWORD_SALT'])
    except:
        flash('The password reset link is invalid or has expired.', 'danger')
        return redirect(url_for('login'))
    #user has passed tests, allow resetting of password

    if request.method == 'GET':
        return render_template('passwordReset.html', token=token)

    if request.method =='POST':
        password = request.form['password']
        confirm_password = request.form['confirm_password']

        if not complex_password(password):
            flash('Password requirements not met', 'danger')
            return render_template('passwordReset.html', token=token)

        if password != confirm_password:
            flash('Password confirmation does not match password', 'danger')
            return render_template('passwordReset.html', token=token)

        db_connection = connect_to_database()
        hashed_password = generate_password_hash(password, salt_length=8) # salt and hash password
        print(email)
        query = ('UPDATE `users` SET pword = %s WHERE email = %s;')
        data = (hashed_password, email)
        cursor = execute_query(db_connection, query, data)
        cursor.close()

        flash('Your password has been reset.', 'success')
        db_connection.close() # close connection before returning
        return redirect(url_for('login'))
```

Credential Stuffing

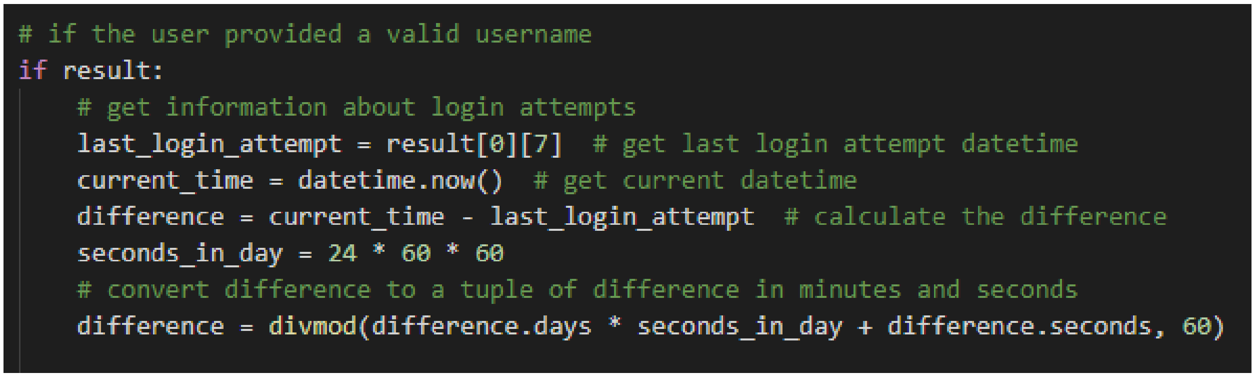
Brute Force

To strengthen our secure site against brute force attacks attempting to log in to our site, if an account fails to provide the correct password three times in five minutes, they will be locked out of the account for five minutes. With this restriction in place brute force attacks will be drastically less effective since the attacker will be limited to three guesses per five minutes. This makes it much more difficult for a brute force attack to succeed since it will take significantly longer to try possible passwords.

One potential drawback of implementing an account lockout is that a user who is the target of a brute force attack could have their account locked at no fault of their own; however, the lockout is only 5 minutes, so we believe this risk and inconvenience is worth the added security.

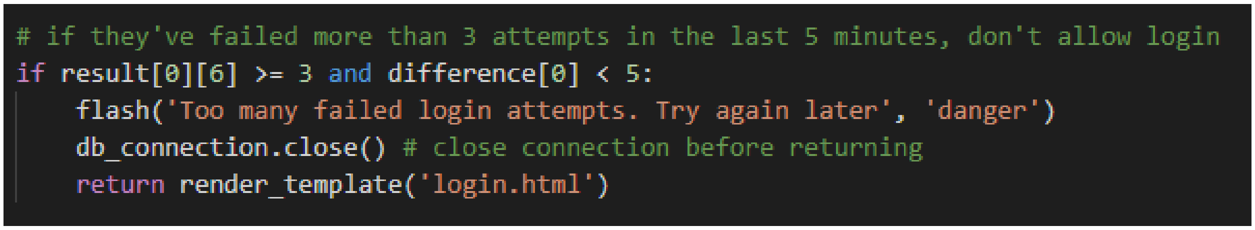
To implement this, we modified our login route in the following ways:

Query for timestamp of the last login attempt for the username and calculate the elapsed time between that timestamp and the current time.



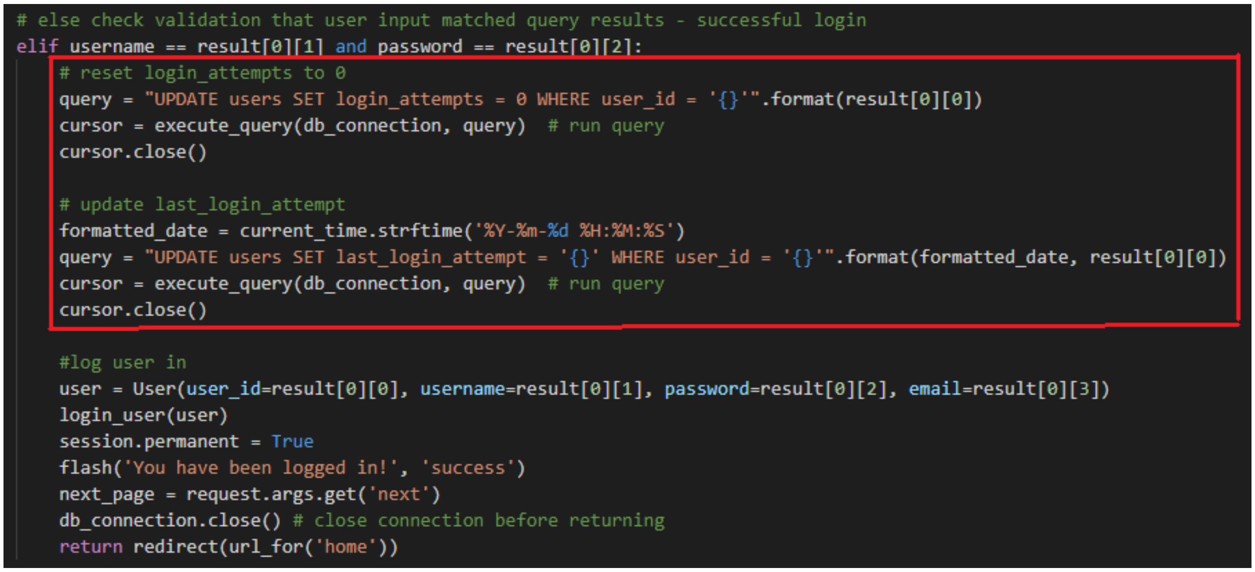
```
# if the user provided a valid username
if result:
    # get information about login attempts
    last_login_attempt = result[0][7]  # get last login attempt datetime
    current_time = datetime.now()  # get current datetime
    difference = current_time - last_login_attempt  # calculate the difference
    seconds_in_day = 24 * 60 * 60
    # convert difference to a tuple of difference in minutes and seconds
    difference = divmod(difference.days * seconds_in_day + difference.seconds, 60)
```

If there have been more than 3 failed attempts and less than 5 minutes have elapsed since the third failed attempt, do not process the login information, and display an error.



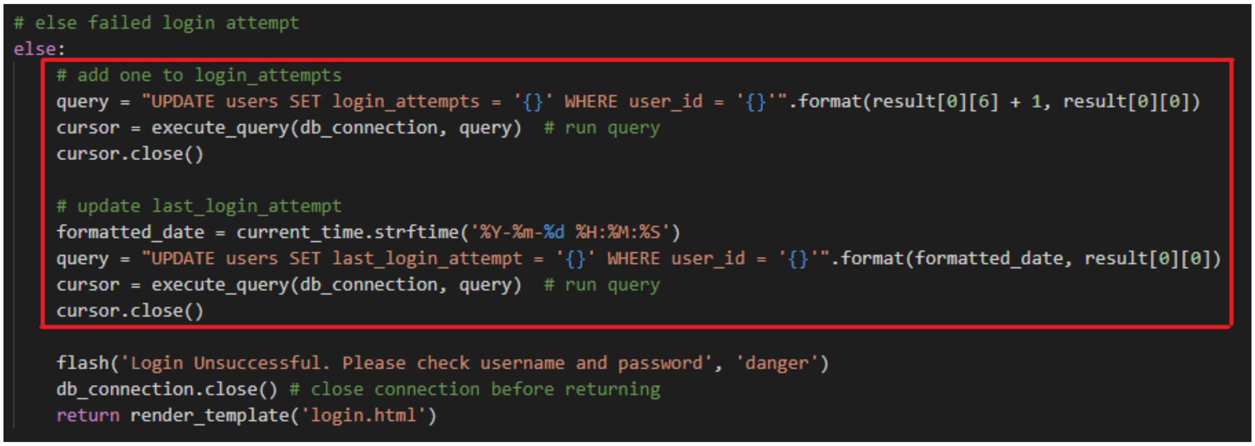
```
# if they've failed more than 3 attempts in the last 5 minutes, don't allow login
if result[0][6] >= 3 and difference[0] < 5:
    flash('Too many failed login attempts. Try again later', 'danger')
    db_connection.close() # close connection before returning
    return render_template('login.html')
```

Else, if the provided username and password match what is stored for the user, then the login is successful, so their ‘login_attempts’ is reset to 0 and their ‘last_login_attempt’ is updated before logging them in and redirecting to the home page.



```
# else check validation that user input matched query results - successful login
elif username == result[0][1] and password == result[0][2]:
    # reset login_attempts to 0
    query = "UPDATE users SET login_attempts = 0 WHERE user_id = '{}'".format(result[0][0])
    cursor = execute_query(db_connection, query)  # run query
    cursor.close()

    # update last_login_attempt
    formatted_date = current_time.strftime('%Y-%m-%d %H:%M:%S')
    query = "UPDATE users SET last_login_attempt = '{}' WHERE user_id = '{}'".format(formatted_date, result[0][0])
    cursor = execute_query(db_connection, query)  # run query
    cursor.close()

    #log user in
    user = User(user_id=result[0][0], username=result[0][1], password=result[0][2], email=result[0][3])
    login_user(user)
    session.permanent = True
    flash('You have been logged in!', 'success')
    next_page = request.args.get('next')
    db_connection.close() # close connection before returning
    return redirect(url_for('home'))
```

Else, the provided username and password do not match, so the ‘login_attempts’ for the user is incremented and their ‘last_login_attempt’ is updated before displaying an unsuccessful login message.



```
# else failed login attempt
else:
    # add one to login_attempts
    query = "UPDATE users SET login_attempts = '{}' WHERE user_id = '{}'".format(result[0][6] + 1, result[0][0])
    cursor = execute_query(db_connection, query)  # run query
    cursor.close()

    # update last_login_attempt
    formatted_date = current_time.strftime('%Y-%m-%d %H:%M:%S')
    query = "UPDATE users SET last_login_attempt = '{}' WHERE user_id = '{}'".format(formatted_date, result[0][0])
    cursor = execute_query(db_connection, query)  # run query
    cursor.close()

    flash('Login Unsuccessful. Please check username and password', 'danger')
    db_connection.close() # close connection before returning
    return render_template('login.html')
```

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